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# The SCIENTIFIC MONTHLY

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VOL. LXIX NO. 4 OCTOBER

**thoroughly clean pipettes . . . at great savings in labor and breakage costs**

# technicon

## AUTOMATIC PIPETTE WASHER

In a few brief minutes, through its unique flush-action washing principle, The Technicon Pipette Washer delivers a full basket load (200 of 1 ml in 100th's) of scrupulously clean pipettes, ready for drying in the same basket. No handling of individual pipettes, no shifting from one container to another . . . the entire process of cleansing, washing and drying is carried through without fuss or bother. We will be glad to send you a bulletin giving particulars of this remarkably efficient laboratory appliance.

**THE TECHNICON COMPANY**
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the efficient Technicon washing principle is graphically shown in these schematic views

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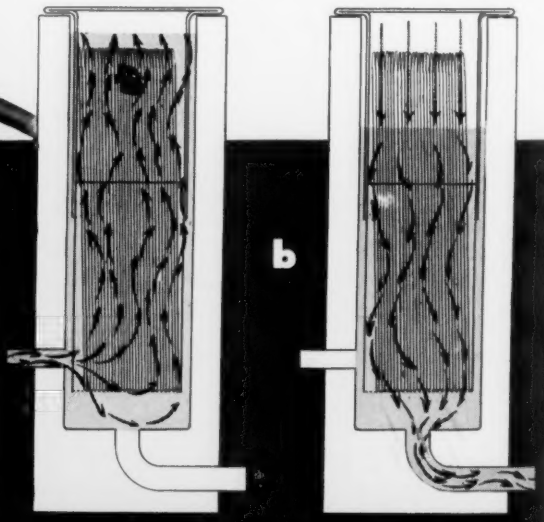


*(a) Schematic view showing washer, loaded with pipettes, immersed in Technicon washing chamber. Water surges in at inlet, passing upward through open-mesh floor of rack, sweeping through pipettes, until it reaches top level shown.*

*(b) When water has reached top, the outlet valve opens. Water then flushes out rapidly, sucking through pipettes, and carrying away wastes and residues. Water is under pressure, in violent turbulence, during entire cycle.*

THE
SCIENTIFIC MONTHLY

OCTOBER 1949

# FOOT-AND-MOUTH DISEASE—A HAZARD TO THE WORLD'S FOOD SUPPLY

H. W. SCHOENING

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IN DECEMBER 1946 an announcement was made from Mexico City which had far-reaching implications and which resulted in a gigantic international cooperative battle against one of the most feared of the world's livestock plagues. This announcement was that foot-and-mouth disease had been found in the Republic of Mexico. It was a matter of grave concern to the livestock industry of both the United States and the Republic of Mexico, since this disease had not appeared on the North American continent since 1929.

Foot-and-mouth disease, caused by a filtrable virus, gets its name from the fact that vesicles, or blisters, form in the mouth parts, particularly the tongue, and between the claws on the feet. The disease produces severe lesions in the mouth and on the feet. It has a general effect on the animals with a rise in temperature, since the blood stream is invaded temporarily by the virus. Milk flow is decreased, and the animals lose weight. The disease is complicated in many instances by secondary infections involving the feet and rendering the animals more or less helpless. The average mortality is about 3–5 percent, but in some years, in countries where the disease is epizootic, the mortality may reach as high as 50 percent of some herds. The aftereffects on the animals are sometimes long-standing, and in dairy animals the milk supply is depressed for many months. Abortions and mastitis, an inflammation of the udder, frequently follow an attack of foot-and-mouth disease.

The disease is one of the scourges of the livestock industry. It has existed in many countries for years, despite strenuous efforts on the part of the livestock sanitary officials of those countries to bring about its control. Cattle, swine, sheep, and goats are primarily affected, although all ruminants and cloven-footed animals are susceptible. Man is quite resistant, and authentic reports of cases in the human family are very rare. The damage caused by the disease, in the reduction of supplies of meat and meat food products and milk, when once it becomes established in a country, runs into high figures. The United States, through its Federal Bureau of Animal Industry and its state livestock sanitary services, has been and is on guard against the introduction of the disease into this country. Since the turn of the century, however, the disease has been introduced into the United States five times—in 1902, 1908, 1914, 1924, and 1929. In each instance, it was eradicated within a comparatively short time through the stamping-out, or slaughter, policy, which is predicated on the early recognition of the disease, the slaughter of all infected and exposed animals, disinfection, and quarantine measures.

The proximity of the disease in Mexico, where its existence was established through the investigations of veterinarians from the Mexico Depart-



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ment of Agriculture and the Bureau of Animal Industry, United States Department of Agriculture, immediately brought realization of the danger to the livestock industry of the United States. It was apparent that unless active steps were taken to control and eradicate the disease in Mexico, it would soon spread northward and eventually cross the border into the United States. As soon as the presence of the disease in Mexico was determined, a quarantine was immediately placed by the United States on the United States-Mexico border. This prohibited the movement of susceptible species of livestock from Mexico into this country. Since the cattle industry in the northern part of Mexico annually exported to the United States about 500,000 animals, this embargo was a severe blow to the economy of the northern part of Mexico. The Mexican officials were cognizant of the effects of foot-and-mouth disease upon the livestock industry of the country and were anxious to control and eradicate it.

Conferences were held between the officials of Mexico and the United States to bring about cooperative efforts to control and eradicate the disease in Mexico. The Secretary of Agriculture asked Congress for authority to assist the Mexican government in the eradication of the disease through the stamping-out policy. Legislation to this effect was passed by Congress. Funds were provided whereby a joint effort to stamp out the disease was undertaken by the two governments. A Mexican-United States Commission for the eradication of foot-and-mouth disease was established, with headquarters in Mexico City. Forces including veterinarians, technicians, business administration clerks, etc. from the United States and Mexico were recruited to start the campaign of eradication by the stamping-out, or slaughter, method, which has been so successfully used in the United States and England. It took considerable time to develop the organization and to provide equipment necessary for the slaughter of the infected and exposed animals and for their disposal through deep burial. The extent of the disease was determined, and quarantine lines were established to prevent the spread of the disease beyond the quarantined area. Efforts were then directed to eradication within the area through the slaughter of infected and exposed animals.

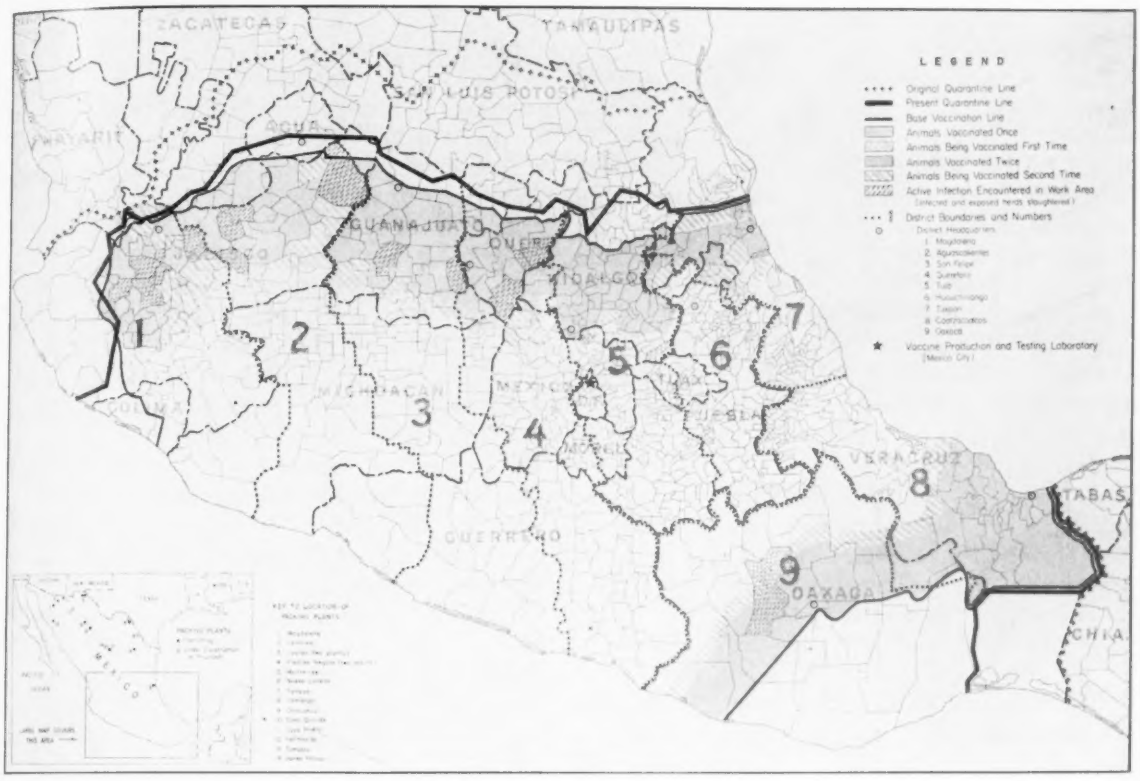
The disease was definitely diagnosed in December of 1946, but there are indications that it had existed for perhaps two months previously. The infection was first diagnosed in the vicinity of Puebla, about fifty miles from Mexico City, where it had spread from the Gulf Coast in the State of Vera Cruz. The accompanying map shows the infected area with the northern and southern quarantine zones.

The task of stamping out the disease was a tremendous one. Many difficulties were encountered in carrying out the program, despite the best of cooperation between the officials of the two governments. There was opposition on the part of cattle owners, since they were not familiar with the disease and the necessity of stringent measures for its eradication. Information forces worked hard through newspapers, motion pictures, radio, and direct contacts to promote understanding of the program. The Mexican National Army is responsible for enforcement of quarantine and other orders and for protection of the control forces. The disease had gained much headway before the stamping-out program could get into full speed.

The impact of the extensive slaughtering on Mexican economy was a matter for serious consideration by the Mexican officials, and in November of 1947 the Mexican government insisted that it could no longer continue the program because of the damaging effect upon the economy of the country. It requested the United States to revaluate the program of vaccination, slaughter, and quarantine. A new program was instituted by mutual consent of the two governments in November 1947, with procedures based on maintenance of the quarantine lines, repeated inspections, and vaccination of all susceptible animals in the quarantined area as quickly as possible, together with a modified slaughter program.

The development of an effective vaccine against foot-and-mouth disease has been based on extensive research done over the years in various countries of the world where foot-and-mouth disease is enzootic. The first indication that an active immunity could be established in cattle through the use of an inactivated vaccine was reported by Vallée of France in 1924. He showed that it was possible at that time to produce immunity under certain conditions with a vaccine in which the virus of foot-and-mouth disease was inactivated by formalin. This type of vaccine was irregular in its results but furnished a lead for other workers to build upon.

In 1934 Schmidt of Denmark showed that it was possible to produce immunity with a vaccine in which the virus of foot-and-mouth disease was adsorbed on aluminum hydroxide. This method was further studied by Waldmann of Germany and his co-workers and resulted in the development of the present-day vaccine which utilizes




Infected area and quarantine zones.

the virus of foot-and-mouth disease adsorbed on aluminum hydroxide rendered inactive by the addition of formalin. This is known as the Schmidt-Waldmann type of vaccine and is the one that has had extensive use in Europe.

Modifications of this type of vaccine have been made in South America and Mexico by utilizing the principle of adsorbing the virus on aluminum hydroxide and the addition of formalin. The Schmidt-Waldmann type of vaccine as prepared in Europe is injected into animals subcutaneously in doses of 30 cc, whereas the modification of the vaccine in Mexico calls for the injection of 2 cc intradermally.

Briefly, the vaccine is made as follows: A number of cattle are inoculated on the tongue with the virus of foot-and-mouth disease in a very active form. At the end of twenty-four hours there is a marked multiplication of the virus at the sites of inoculation, the so-called primary vesicle of the disease. The animals are slaughtered at this stage of the disease when a multiplication of the virus has occurred only at the site of inoculation and blood infection has not yet begun. After the animals are slaughtered, the tongue is removed, the epithelium containing vesicles filled with fluid is stripped off, and this material is processed into the final vaccine. The animals are dressed in the abattoir in the usual way, and the meat is sold for food after inspection. The previously harvested virus is then ground through very fine mills and proper diluents added to extract the virus from the tissues. The material is finally centrifuged and the virus collected in solution. The appropriate amounts of aluminum hydroxide are added and, finally, 0.05 percent formalin to kill the virus. The material is kept at a temperature of 25° C for 72 hours and then is bottled as the final step before it is ready for use. Tests of the finished product are made for innocuity or safety; that is to say, the vaccine is tested on cattle for the presence of active virus. Each lot of virus is also subjected to potency tests. A group of twenty animals is vaccinated intradermally with 2 cc of the virus. Fourteen days later half of these animals are exposed to the virus by inoculation on the tongue, the other half are exposed by contact to infected animals. An appropriate number of control animals checks the activity of the virus used in exposure. Only those vaccines which protect animals completely against generalization of the disease are considered to be satisfactory. These vaccines have previously been determined to contain no active virus. It has been possible to grow the virus of

foot-and-mouth disease in tissue culture using the epithelial tissue of guinea pigs and calf fetuses.

In more recent years Dr. Frenkel of Holland has developed a technique whereby it is possible to grow the virus of foot-and-mouth disease in tissue culture, using tongue epithelium. This latter method has been used in the production of small experimental lots of vaccine with considerable success and is a project which has a promising future as a means of developing a virus sufficient for vaccine production in the test tube rather than in the animal as is now the case.

Until very recently attempts to grow the virus of foot-and-mouth disease in the embryonated hen egg have not been successful. A recent report from Germany indicates, however, that a strain of virus had been adapted to growth in the embryonated hen egg as a result of considerable experimentation during the war. No confirmation of this work has yet been forthcoming, but it opens a new lead in attack upon the problem of the artificial propagation of the virus of foot-and-mouth disease.

After the outbreak of the disease in Mexico, arrangements were made to have the European laboratories conduct necessary typing tests of the virus prevailing in Mexico and to furnish vaccine for the Mexican program until such time as facilities could be made available for the production of a similar product in Mexico.

The problem of preparing sufficient quantities of vaccine in Mexico was a big undertaking, since it required not only facilities for inoculating large numbers of animals but also extensive facilities for harvesting and processing the virus into vaccine and, finally, the testing of all lots of vaccine for safety and potency before use in the field. Facilities were finally made available in Mexico for the production and testing of vaccine. This work is carried out through the joint Commission by Mexican and American personnel. Starting in May of 1948 small quantities of vaccines were produced. As the facilities increased, the production and testing of the vaccines increased, and at the same time a field organization was established for the vaccination of cattle in the field. Great strides have been made in the vaccination program, and at the present time more than 2 million doses of vaccine are being prepared monthly. Vaccination of cattle, swine, sheep, and goats in the quarantined area is proceeding at a comparable rate. Since it has been found that in some instances vaccination produces an immunity for approximately four months only, the interval between vaccinations is routinely set at four months. Active infection as it is encountered is eliminated through slaughter.

The task of organizing this program so that it functions smoothly is an enormous one. Inspectors in the field in certain areas have a mountainous terrain to work, and others are in a tropical jungle country. The vaccines used must be kept at low temperatures at all times, and the proper transportation of the vaccine under these conditions is a major problem. Airplanes, trucks, wagons, pack animals—all are utilized to move the vaccine to the "front lines." The collection of all animals for inspection and vaccination, the delivery of vaccine at the proper place at the proper time in sufficient quantities, the task of preparing sufficient quantities of potent vaccine—these are factors which must be highly coordinated and integrated. In order to carry out the over-all plan of operations, which is aimed at progressive constriction of the quarantined area, it is necessary to vaccinate the largest number of animals in the shortest possible time. So far the program of vaccination has been favored by the fact that only Type A virus has been found in Mexico. Three types of virus, designated A, O, and C, are recognized in other countries. If other types of virus are found in Mexico, it will be necessary to prepare vaccines against these types, since vaccine prepared from one type does not immunize against others.

The program in Mexico is the largest of its kind that has been attempted in any part of the world. The officials of the Mexican-United States Commission are encouraged with the progress made so far, although it is too early to evaluate the results critically. The outbreak of the disease in Mexico has focused attention on the need for research work on foot-and-mouth disease by the United States in order that we may be better prepared in the event of an outbreak in this country. No research work, as such, on foot-and-mouth disease has been done in the United States in the past, although the Bureau of Animal Industry has been cognizant of the research work done in other countries, and in 1925 formed a commission of three scientists to study the disease in European countries and laboratories. The information that has been accumulated in the past twenty years has been limited, owing primarily to the fact that, in general, large animals (cattle) are needed in experimental work. This is extremely expensive, since many animals are needed, and it is imperative that these be housed in strict isolation for the proper conduct and evaluation of experimental work. Much information is necessary before the

whole problem of foot-and-mouth disease control can be evaluated.

After careful consideration, the Bureau of Animal Industry has taken the stand, which has been supported by the livestock industry of the country, that research on foot-and-mouth disease should be undertaken by the United States Department of Agriculture. Legislation has been enacted authorizing the conduct of such research on a coastal island of the United States. Funds for this work have not yet been appropriated. In the meantime, however, a temporary research program on foot-and-mouth disease is being carried out by the Bureau in cooperation with several of the institutes in European countries, namely, in the Netherlands, Denmark, and England. The Bureau has representatives actively engaged in research work at these institutes. Thus the Department is training personnel in studying foot-and-mouth disease and the various techniques used in experimentation with it. The control of foot-and-mouth disease and research on the problem are receiving attention on an international basis. They have been the subjects of consideration at several meetings of the International Office of Epizootics in Paris, as well as the Food and Agriculture Organization of the United Nations. The accompanying map shows the present infected territory in Mexico and some details of the vaccination program.

The infectiousness of the disease, the damage to livestock, the rapidity with which it spreads, the difficulty of controlling it despite quarantine measures, which in themselves are restrictive and costly, make it a disease of the greatest economic importance. It is estimated that, should foot-and-mouth disease become established in the United States, the average annual monetary loss would be 200 million dollars. Much information has accumulated over the years giving help in the control of the disease. Much has been accomplished through the development of present-day vaccines. A comprehensive program of research will considerably improve this vaccine and the methods of control. The knowledge obtainable will be to a great extent dependent on the amount of research that can be done. The research laboratory proposed by the United States will be the largest of its kind in the world, and here large-scale experiments could be conducted with safety and efficiency. This should give, within a reasonable period of time, many of the answers now needed on the foot-and-mouth disease problem.

## AUTUMN IS THE LISTENING TIME

The air is clear
Save for the counterpoint—
The south-winged whooshing
Of the cranes,
The chant of chickadees,
The velvet pat of doves,
The myriad hum of pollen-sowers.
But that's not all;
Within the hollow of the hill
The tractors throat a score
To puffs of powdered earth;
A migrant train
Adds plaint and argument.
But there is gladness in lament.
The spires in the valley's cup
Wear bells
Which now and then
Discuss with merriment and humor
All the virtues on the earth
And in the heavens too.

JOSEPH HIRSH

# SMOG AND SONICS

VINCENT SALMON

*Born in Jamaica, B.W.I., Dr. Salmon moved with his parents to the United States shortly before World War I. He became a naturalized citizen and was reared and educated in this country (Ph.D., MIT, 1938). In 1946 he received the biennial award of the Acoustical Society of America for his invention of a new family of acoustical horns. Dr. Salmon is head of the Sonics Section of the Stanford Research Institute's Physics Research Department.*

THE history of man's attempts to subjugate nature is replete with instances of her retaliation for any upsetting of the delicate balance of natural processes. An example of this, often much too familiar to those living near large concentrations of industry, is "smog." Originally the word "smog" was coined to describe a mixture of smoke and fog, such as, for example, that formerly present in a severe form near Pittsburgh and St. Louis; now, however, its meaning has been extended by popular usage to apply to any set of atmospheric conditions in which smoke, fumes, and fog, alone or in any combination, have reached a nuisance level evinced by excessively reduced visibility, with perhaps undue eye, nose, and throat irritation.

Severe smog usually occurs when certain natural meteorological conditions combine with a continuous outpouring of excessively contaminated gases from such processes as combustion of fuels, smelting and refining of metals, production of petroleum, and general chemical operations. The contamination consists of both particulate and gaseous components; the former includes vapors and liquid droplets as well as solid particles. In what follows we shall be concerned with the conditions leading to the formation of smog and the role played by the particulate components. Finally, the removal of these components by sonic means will be considered in some detail.

## FORMATION OF SMOG

Normal weather is variable weather—that is, if conditions of temperature, humidity, wind velocity, etc. at any one location remain steady for any length of time, we consider that unusual. There are, however, some steady patterns of meteorological behavior which attain a quasi-stable state for considerable periods, and constitute more or less normal behavior. The example pertinent to our discussion is the predominantly seasonal formation of a semipermanent temperature inversion layer over the western shores of most continents, and occasionally in the interior. Normally, air temperatures should decrease (lapse) as one recedes from the ground, but in approaching an inversion the initial decrease, or lapse, rate becomes slower, finally reversing sharply, then again finally decreasing. This is portrayed in Figure 1; the boundaries of the inversion layer are marked by the changes in slope, which often are as sudden as indicated.

Within the inversion layer the motion of the air is remarkably uniform in magnitude and direction; hence the discharge from a stack that pierces the layer will stretch out as a long plume, which mixes but slowly with the surrounding air. If the smoke is given an appreciable initial upward component of velocity from the stack, it will continue to rise as long as its temperature is above that of the ambient air. As it rises, however, it expands and therefore cools, and thus at the most can go little higher than the top of the inversion layer, when the lapse rate again becomes normal.

Under conditions of excessive atmospheric contamination plus an inversion, material may be collected in the inversion layer and be discernible as a thick haze, particularly if the geography is such as to wall off the escape of incoming winds. Suppose that for various reasons the inversion layer gradually approaches the ground. In doing so it encounters the turbulent surface winds, which thoroughly mix the contamination layers to form the thick blanket we call smog. Conditions are worsened if in addition there is a fairly long period of low wind, low atmospheric moisture content (mixing ratio), and above-normal temperatures. It was probably an acute combination of such conditions that led to the "death smogs" of 1930 in the Meuse Valley in Belgium and of 1948 in

Donora, Pennsylvania. The deaths traceable to these smogs numbered around 63 and 20, respectively, a rather high price to pay for preventable tragedies.

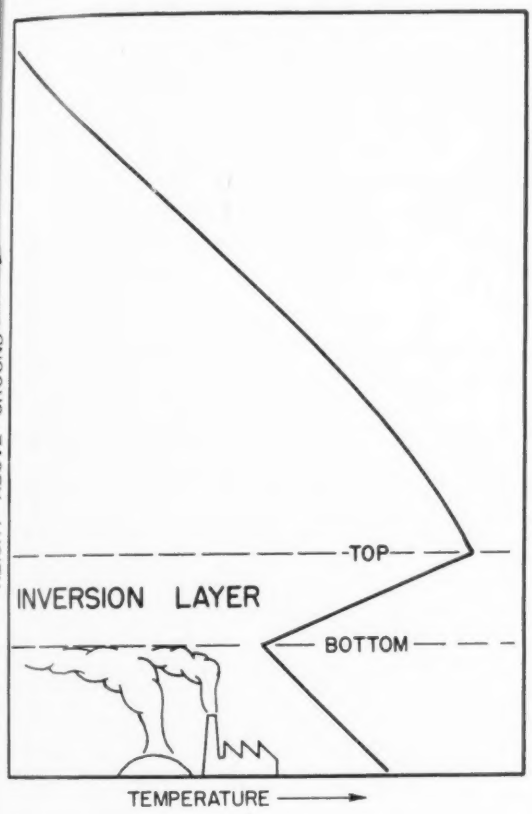



FIG. 1. Temperature-altitude relation with inversion present.

## SOURCES OF AIR POLLUTION

Much of our air pollution is due to the smoke arising from the incomplete combustion of soft coal, among such users as householders, power plants, and railroads. Since smoke represents wasted fuel, many economy-minded industrial users have installed more efficient combustion equipment, whose discharge is barely noticeable. Also, the University of Illinois has been instrumental in developing a downdraft soft-coal heater for household use which bids fair to effect considerable reduction of contamination from this source. The best means of preventing combustion-caused pollution is simply the use of better combustion equipment, a fact that is now well recognized.

In the ore-refining, metals-smelting, and heavy-chemical industries, some processes normally result in aerosols comprising fumes and dusts of such fine particles that removal by conventional means is difficult. Often the solid component is the semifinal product, and inexpensive means of collecting the fumes (which are finer than dusts) would not only reduce contamination of the atmosphere, but would also furnish additional income. Considerable thought and effort have been put into this problem for many years, but no universal means of precipitating all types of particles has been found. Rather, each problem must be considered individually, and the optimum collection means found in each case may well turn out to be a combination of several simpler ones. Recent and widespread efforts to alleviate air pollution have led to the search for new methods of removing very fine particulate matter of submicron size from such hot aerosols as stack gases, and have resulted in the rapidly increasing industrial use of sonic methods of glomeration. In this process, intense sound is used to increase the average size of a clump of particles so that they may readily be removed by other means.

## COLLECTING MEANS

Let us digress at this point to indicate the generally used methods of clearing gases of particulate components. Classification of the means of separation at present available may be set forth as follows:

1. Separation by a field of force which acts differently on the gas molecules and on the particulate matter.
   - Centrifugal (cyclones)
   - Electrostatic (Cottrell process)
   - Gravitational (sedimentation chambers)
2. Separation by relative motion between gas molecules, suspended particles, and some obstruction with selective action.
   - Oscillatory motion
     - Ordered motion (sonic glomerators)
     - Random motion (thermal precipitators)
   - Unidirectional motion
     - Impingement (impingement scrubbers, packed towers, mechanical washers)
     - Filtering (textile, fiber, ceramic, metal)
     - Bernouilli mixing (Venturi scrubber)

All the means of separation outlined above also involve some glomerating action. Whether by the action of a field of force or by velocity differences, the particles to be removed will experience increased numbers of collisions with one another. Theoretical studies have confirmed the observed fact that colliding particles naturally tend to cohere to form larger ones. This is particularly true in sonic glomeration. As ordinarily used, sonic

glomerators are employed to increase the size of clumps of particles until the minimum size is well within the operating range of another device, whose main function is that of separating and collecting the suspended "flocs," as the groups of primary particles are called.

### SONICGLOMERATION

In a discussion of some of the elementary notions about sound, we may first note that the word "sound" refers to both the sensation and to the physical cause. Physically, the presence of a sound wave is shown by the more or less ordered vibration of the particles of the medium through which the wave passes. In most cases of interest to sonic glomeration, we deal with waves that are approximately plane and are of closely sinusoidal wave form. By this is meant that the time variation of gas molecule displacement from equilibrium is a sine curve, and that points having the same phase of motion lie in a plane. We may measure the strength of such a wave by its displacement, velocity, acceleration, temperature change, pressure change, or density change, depending on the work it has to do. Here let us use the maximum displacement, or displacement amplitude, as a convenient measure of the strength. Then if the plane wave exists in a medium with absorption, a plot of amplitude versus distance along the direction of propagation will show a gradual exponential decrease of amplitude, provided that no reflected wave is present. This slow change is shown schematically in Figure 2*a*, and characterizes what is called a traveling wave.

If we now place perpendicular to the wave a large plane piece of material which is an imperfect reflector—that is, it has finite stiffness, mass, and internal dissipation—the reflected wave will then interfere with the direct incident one to produce the amplitude variation pattern of Figure 2*b*, which characterizes a standing wave. Note that the maximum amplitude is not obtained at the reflector, but some distance in front of it; this is due to its finite stiffness and mass. Also, the minimum amplitudes are not zero; this arises from dissipation of energy in the reflector. The gradual change in the minima arises, as in Figure 2*a*, from absorption in the medium. When the reflector is perfectly rigid and the medium still has some absorption, the pattern changes to that of Figure 2*c*, which most closely approaches conditions in a sonic glomerator stack. Here the maxima have been increased, whereas the minima are still dependent on absorption in the medium. The maxima are also affected by absorption, but this is a second-order effect that is not noticeable unless the absorption is quite high.

When a generator of sound works into a column of air in a rigid pipe, the maximum displacement amplitudes are attained when, in electrical engineering parlance, the reaction back on the ultimate source is entirely resistive. This condition is called resonance, and merely increases the amplitude in some regions at the expense of lessened amplitudes elsewhere. In terms of the standing wave pattern of Figure 2*c*, the source must be operating at the correct position and frequency to obtain resonance.

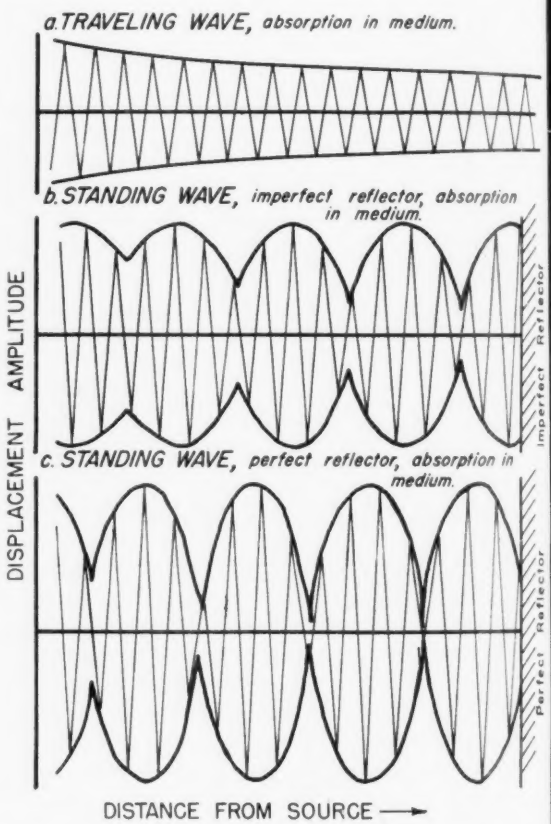

a. TRAVELING WAVE, absorption in medium.
b. STANDING WAVE, imperfect reflector, absorption in medium.
c. STANDING WAVE, perfect reflector, absorption in medium.
DISPLACEMENT AMPLITUDE
Imperfect Reflector
Perfect Reflector
DISTANCE FROM SOURCE

FIG. 2. Amplitude-distance variation in plane sound waves under various reflecting conditions.

It was observed in 1866 by the German physicist Kundt that a fine dust of lycopodium powder lying in a horizontal glass tube would collect and pile up at the regions of maximum gas molecule vibration in an intense standing wave set up in the air within the tube, using a perfect reflector. The effect remained a scientific toy until the 1930s, when

there was renewed interest in the phenomenon. It was known that if an aerosol were introduced into a strongly resonant air column the suspended small particles would glomerate into larger particles, or flocs, which collected at the positions of maximum amplitude. These flocs were found to grow to be so large and heavy that they easily settled out in the absence of any body motion of the gas.

Much work has gone into making this phenomenon the growing industrial tool it is in modern sonic glomerators. An intense source of sound is necessary for the rapid and effective glomeration of aerosols, and is usually a special siren which can interrupt a stream of air at rates from 1,000 to 30,000 times per second. One commercially available model is capable of producing at its mouth a sound intensity of more than 6 watts per square inch. The acoustical engineer will perhaps understand this better as a sound pressure level of about 160 dbp (dbp is the unit of sound pressure level in decibels above 0.0002 dyne/sq. cm). As this is more than 1,000 times the power at which the ear first perceives pain, one of the problems in such installations is adequate sound insulation, especially if the siren is operated in the audible range. Although sound will not be heard if its frequency is above this range, which ends between 15,000 and 20,000 cycles per second, some laboratory workers have experienced fatigue, headaches, and even nausea after considerable and extreme exposure. It must be emphasized, however, that there is no evidence that moderate exposure is permanently harmful; it is known that many susceptible individuals will develop the symptoms simply by suggestion. In any event, it is an easy matter to provide adequate insulation at the frequencies used.

Investigators have observed that as the acoustic power to a glomerating column is increased, there is little effect until a threshold power is attained; thereafter the glomeration rate increases rapidly. For many initial applications this threshold has been found to be near 0.5 watt per square inch. Since the aerosol is usually passed continuously through the glomerating column, the large flocs that form have no opportunity to settle out. Their final removal may be accomplished by utilizing additional means, such as electrostatic precipitators, centrifugal separators, bag houses (cloth bag filters), etc. The maximum acoustic power that may be employed is dictated by reasons of economy; there is no need to make the flocs any larger than necessary for efficient removal by the final separating device.

In Figure 3 are shown the essential parts of a sonic coflector in the form at present used. The sound field is set up in a cylindrical stack, all of whose walls are rigid and highly reflecting toward sound. The bottom opens into the final separator, here a cyclone, and the top is terminated by the gas inlet and by the source of sound, usually a siren; these relative positions avoid fouling of the generator. The frequency of the siren is set to provide a fully developed standing wave (resonance) so that the maximum oscillatory velocity of gas molecules is attained. As indicated in Figure 3, this occurs in regions which are half a wave length apart in the uniform portion of the stack; the maximum nearest the bottom will be close to a quarter wave length from the plate closing the bottom. These exact relations are disturbed not only by inhomogeneities in the composition of the aerosol, but also by the presence of the inlet, outlet, and sound generator facilities.

Since absorption increases markedly with frequency, most glomerators work at lower frequencies, well within the audible range. If the aerosol is principally air at 900° F. and atmospheric pressure, then at a frequency of 2,700 cycles per second the regions of maximum particle velocity are about 4 inches apart. Under these conditions a 15-foot stack would have about 40 useful maxima, affording ample opportunity for glomeration. Thus, when the aerosol is finally passed on to the collecting device which follows, the particles are larger and fewer, constituting a favorable condition for precipitation by cyclones and electrostatic collectors. If the stack is 4 feet in diameter, with a sound intensity of 6 watts/sq. in., 12 kilowatts of acoustical energy will be required.

One may ask, Why not employ the final separators (as cyclones) for the whole process? The answer lies in the difficulty of using them economically when the size of the suspended particles is much below 5 microns (0.0002 inch); also, at high aerosol temperatures, the ions necessary to the functioning of electrostatic precipitators may sometimes be discharged prematurely. It turns out that sonic glomeration is most useful for the higher temperatures and the smaller particles of micron range and below. In these categories lie appreciable components of such aerosols as stack gases from carbon-black plants, petroleum refineries, metals-smelting plants, and cement factories; sulfuric acid mists from contact-process acid plants; smoke

from burning soft coal and wood; and many types of fly-ash laden gases. In most cases sonic glomeration supplements rather than supplants the other processes of separation; in each application one must weigh the cost against the necessity and desirability of removing the solid particles. With anti-air-pollution legislation receiving considerably more attention, all means of glomeration have to be considered, and the special uses of the sonic type must be kept in mind.

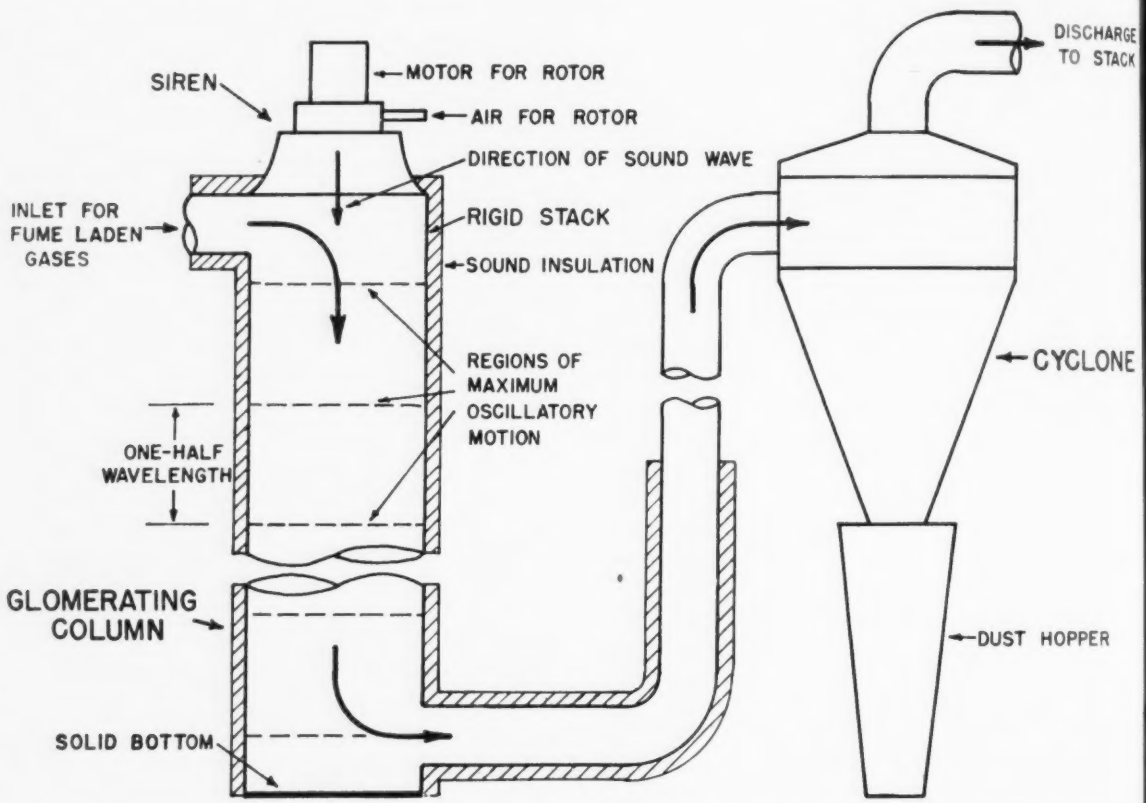



FIG. 3. Essential portions of a sonic dust fume collection system using a cyclone for the final separation.

## MECHANISMS OF GLOMERATION

For all its initial successes in industry, we still do not have enough basic information about the sonic glomeration process to predict the performance with a given aerosol, frequency, and acoustic power. Many explanations have been set forth, and it is likely that all the mechanisms play some part. One of the most obvious explanations is that the suspended particles are carried along by the vibrating gas molecules due to the viscous drag between them. Thus the contaminating particles partake of the motion of the gas molecules to a degree depending on the frequency, gas viscosity and density, and particle radius; this increased velocity makes for more collisions per second between particles of different sizes. From theoretical considerations it is known that a very small particle will cohere to a large one on impact, even if it will not cohere to one of its own size. Thus the colliding particles will glomerate until the resulting floc has reached the size at which it is disrupted by the motion of particles past it. The concept of gas molecules dragging along the suspended particles has proved quite useful in initial calculations for relatively low-frequency glomeration.

To explain the fact that sonic glomeration of extremely fine particle aerosols can take place at relatively high frequencies, recourse is had to three other possible mechanisms. The most plausible is based on the fact that a reflecting surface placed in the path of the wave experiences a pressure known as radiation pressure. This is not to be confused with "sound pressure," which arises from the gas molecules being alternately closer together and farther apart. Rather it is a steady push (with a superimposed "ripple") which tends to urge sus-

pended particles toward regions of maximum motion of the gas molecules. This pressure varies with the frequency, and hence may be expected to be operative mainly at the higher frequencies.

Another mechanism proposed for explaining sonic glomeration calls on Bernouilli forces. These may be simply illustrated by blowing between two sheets of paper held about two inches apart. The far ends of the paper will tend to come together, for they enclose a region in which the air velocity is high compared to that outside, and the Bernouilli law indicates that the pressure in this region will thus be lowered. Similarly, in a resonant glomerating column there will be a force tending to move suspended particles toward the regions of maximum gas molecule motion. The forces evolved are rather too small to be effective, however.

A final suggested explanation for sonic glomeration introduces the concept of vortices, or whirlpools. These may be observed near intense sources of sound; calculations reveal that the vortices should attract one another. This mechanism gives forces that are much too small to explain the observed rapid glomeration, and hence is little used.

All these explanations are still too crude to permit useful calculations of the performance of sonic glomerating columns; they do not explain the threshold effect of a minimum power needed for glomeration, nor is the time factor correctly predicted under all conditions. Much of the discrepancy is due to the assumption that the aerosol contains spherical particles of but one radius; any complete explanation must recognize this as being at variance with the facts. It is likely that no analysis of sonic glomeration will be satisfactory unless the aerosol is considered to be what it actually is—a cloud of gas molecules and solid (or liquid) particles, with a distribution of velocities, sizes, shapes, and cohesiveness specified for each.

The absence of a satisfactory analytical basis for the design of glomerators has not prevented their production and use. Once research has determined the basic relations, however, broadened fields of application and increased efficiency will surely result. Again a scientific plaything is going through the familiar cycle of discovery, research, engineering, and more research, to become a most useful addition to industry's supply of processing tools.

## EDISON AND THE INCANDESCENT LAMP

Just seventy years ago this month Thomas A. Edison placed on test an incandescent lamp with a filament of carbonized sewing thread. For the next forty hours, he and his assistants took turns anxiously watching the light's performance. On October 21, when the lamp continued to burn with a clear, steady glow, Edison triumphantly declared it a success.

The lamp was just the beginning, however—a complete system of electric generation and distribution was necessary to make the invention commercially successful. Edison invented and devised the dynamos, conduits, insulators, fuses, sockets, and meters necessary for the system. One of his most important contributions, according to electrical engineers, was the development of the multiple arc system of current distribution, which made efficient and economical distribution possible. Until this was evolved, it was believed that lighting with electricity would be impractical because all lights on a circuit would have to be either lighted or turned off at the same time.

In his search for a satisfactory filament material, Edison tested hundreds of domestic materials, and his agents scoured the world for strange fibers that might serve the purpose. He carbonized everything—paper, threads, and woods, many of them soaked with tar and other substances. In addition, he experimented with thousands of varieties of plants, canes, and grasses. Finally, he discovered that a very long strip cut from the outer edge of bamboo cane had almost parallel fibers and practically no pith, and by July 1880 carbonized bamboo filaments had replaced the paper carbons that succeeded sewing thread.

In 1882, Edison's Harrison, New Jersey, plant employed about 150 men and had a production capacity of 1,200 lamps a day. Today, the annual sales of incandescent lamps amount to $864,800,000 (according to a government survey of 1947 production), and the three major lamp manufacturers employ approximately 30,000 people in the production of incandescent lamps.

Of the 1,097 patents issued to Edison, 356 deal with the incandescent lamp and the distribution of light and power.

# HELIUM—THE WONDER GAS*

R. A. CATTELL

*Mr. Cattell has been with the U. S. Bureau of Mines since 1921 and chief of the Petroleum and Natural Gas Division since 1933. His special fields are petroleum- and natural-gas engineering and the production of helium.*

HELIUM is the lightest member of the family of monatomic gases composed of helium, neon, argon, krypton, xenon, and radon. It is the nearest thing to nothing that will fill space, exert pressure and do nothing chemically. Hydrogen is a little nearer nothing from the standpoint of weight, but it is very active chemically.

During the dust-bowl era in the Texas Panhandle, the late "Tex" Thornton of Amarillo—one of the nation's best-known oil-well shooters—was called upon to discharge some explosives high in the air near Dalhart, in the hope that the disturbance might cause rain to fall. He rigged up some TNT with a detonator and found a balloon of adequate size to lift the explosives—but when it was suggested that he fill the balloon with hydrogen, "Tex" balked. He told Cliff Seibel, of the Bureau of Mines Helium Plant at Amarillo, that he wanted some helium: "I don't like to fool with hydrogen—it's too dangerous."

Helium is completely safe and for that reason is used in many places where hydrogen might otherwise offer a slight advantage. "Tex" Thornton knew that he might lift a little more TNT with hydrogen in the balloon, but that his chances of seeing the results of the explosion would be better if he used helium.

Nothing happened at Dalhart after the explosion; but the next day "Tex" received a telegram from a friend in Roswell, New Mexico, reading, "Thanks, Tex! We had a nice rain down here."

## DISCOVERY OF HELIUM

The helium story began in March 1866—less than a year after the assassination of Abraham Lincoln. Then, as now, man's curiosity was a driving force, relentlessly pushing him forward in search of more knowledge about things only partly understood. One of the topics of current scientific interest and discussion was the sun and the bright streamers of light that seem to dance on its surface, occasionally reaching far out into space. Not content to marvel at the beauty of these prominences, man began to wonder what they are.

J. Norman Lockyer, then a thirty-year-old clerk in the British War Office, devoted his spare time to the study of astronomy. He believed the solar prominences to be of a gaseous nature, and it occurred to him that he might determine the composition of the gases if he could examine the light from the prominences with a spectroscope. Kirchhoff and Bunsen had laid the foundation for spectrochemical analysis and astrophysics only five years earlier.

Lockyer was confronted by many obstacles. He wanted to develop a device that would obscure light from the body of the sun and, at the same time, permit him to observe the spectrum of light from the prominences. His funds were inadequate and his progress was slow, but by October 1868 he had an especially constructed instrument suitable for his purpose. With it attached to his telescope, he showed conclusively that the prominences gave bright-line spectra, proving that they were immense volumes of gas composed, in part at least, of hydrogen.

In the yellow part of the spectrum, Lockyer noticed a line that was a little nearer the green than the *D* lines of sodium; and in November he fixed the new line at the point called $D_3$. Lockyer became convinced that the $D_3$ line was caused by an element in the sun then unknown on earth, and he called it "helium" from *helios*, the Greek name for the sun.

Although Lockyer was the first to notice the $D_3$ line, P. Janssen, of France, saw the lines of other elements while he was in India observing a total eclipse of the sun in August 1868. Separate and independent reports by Lockyer and Janssen arrived at the French Academy of Sciences a few minutes apart, and a medallion was issued by the Academy commemorating their analysis of the solar protuberances. The two men became close friends.

Father Angelo Secchi, director of the observatory of the College of Rome, independently recog-

* All photographs from the Bureau of Mines.

nized the existence of a new yellow line in the spectrum of the prominences and thus verified Lockyer's observations. Sir Edward Franklin, the distinguished English chemist, assisted Lockyer in proving conclusively that the $D_3$ line could not be caused by any element then known on earth, and that it must represent a new element.

Great men sometimes miss. In 1891 W. F. Hillebrand, of the Geological Survey, had the discovery of terrestrial helium within his grasp, but he missed it. Hillebrand obtained an inert gas from uraninite. The spectroscope showed it to be mostly nitrogen, but the spectrum also contained some lines not identifiable with the mapped ones. Hillebrand did not determine their identity. In March 1895 William Ramsay learned of Hillebrand's work. In his search for argon, he extracted a gas from cleveite, removed the oxygen and nitrogen, and examined the residue with his spectroscope. He saw lines of argon, and, to his astonishment, he also saw the prominent yellow line that Lockyer had found in the spectrum of the chromosphere twenty-six and one-half years earlier. Thus Ramsay became the discoverer of terrestrial helium.

## AIRSHIPS, RADIUM, AND HELIUM

In 1901 the Brazilian Santos Dumont made his seven-mile flight around the Eiffel Tower in a nonrigid airship, more than two years before the Wright brothers' Kitty Hawk made its first successful flight. In 1902 the Curies, French and Polish by birth, isolated radium. In 1903 Ramsay and Soddy, Scottish and English, found that helium is a product of radioactive disintegration, and in that same year, when the natural-gas development of the Mid-Continent area was in its infancy, some Americans drilled a shallow gas well at Dexter, Kansas. Nobody then dreamed that these four events were related.

The gas at Dexter would not ignite, and visions of great prosperity vanished into thin air. When a farmer who piped some of the gas to the firebox of his kitchen range was asked about its heating value, he replied, "Oh, it and wood together make a good fire." A sample of the Dexter gas was sent to the University of Kansas, where it was found to contain only about 15 percent of combustible gases and about 85 percent of nitrogen and other inerts. In 1905 Cady and McFarland found that the gas contained about 2 percent of helium.

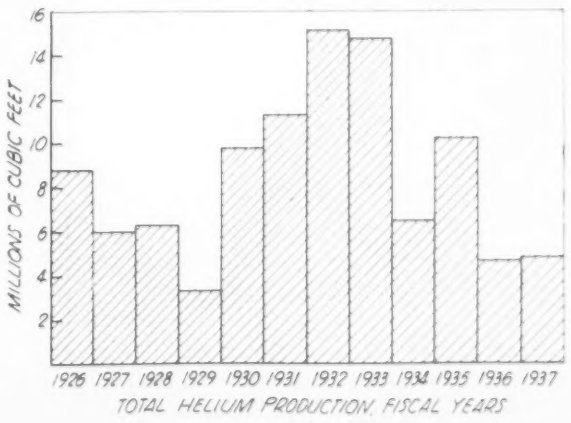
The discovery of helium in virtually nonflammable gas from a small field at Dexter has led to the mistaken conclusion that helium is found only in natural gases of unusually low heating value. On the contrary, nearly all the helium that has been produced in the thirty-two years since the government's helium activities were started has been extracted from natural gas that was being transported to fuel-gas markets. Helium can be extracted economically from poor fuel gases only when the helium content and pressure are very high, the volume is large, and other conditions are favorable. Returns from sale of the natural gas as fuel usually must bear a major part of the cost of developing and operating natural-gas properties to permit recovery of helium at reasonable cost.

All helium-bearing natural gases contain some nitrogen, and some of the gases of unusually high helium content contain large proportions of nitrogen. On the other hand, some natural gases of very high nitrogen content contain virtually no helium.

## HELIUM-BEARING NATURAL GAS

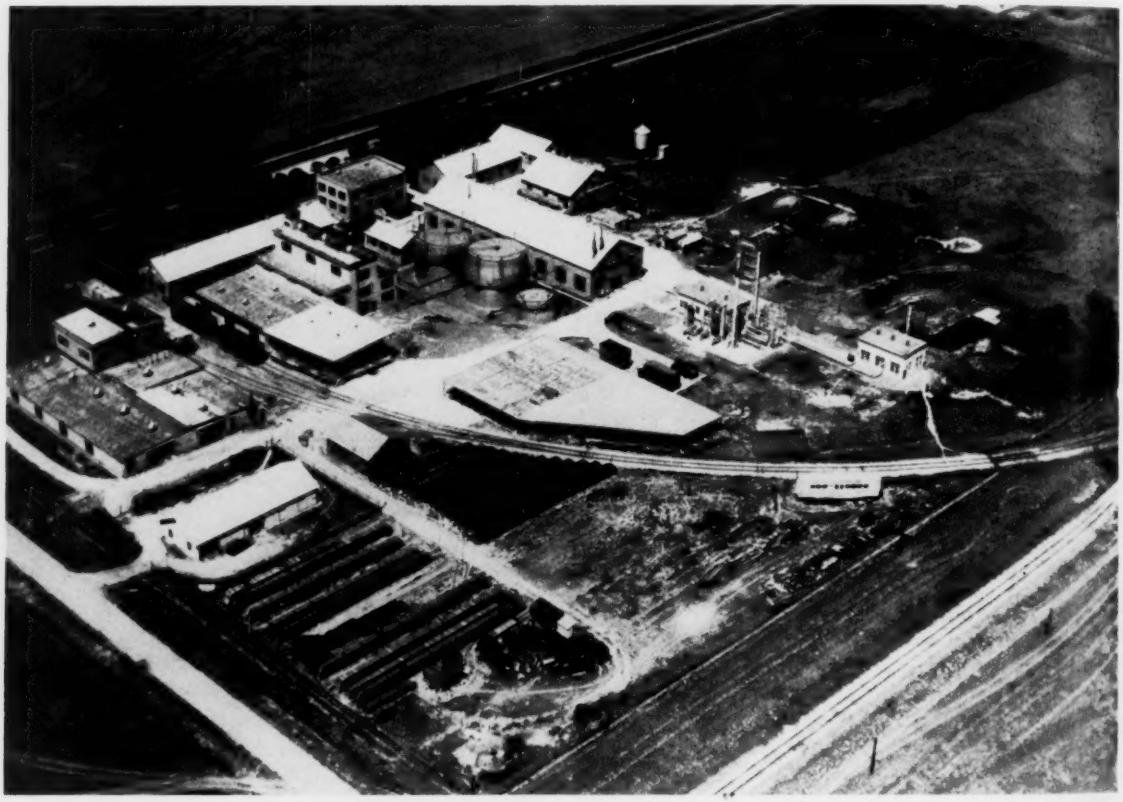
Since helium-bearing gas was discovered at Dexter, gases containing 1–8 percent of helium have been found in a number of fields in Texas, Kansas, Colorado, Utah, New Mexico, and other states. The fields suitable for helium production in large volume at reasonable cost are relatively few, and as helium is a minor constituent of gas that is needed as fuel its conservation is difficult. Nevertheless, fields containing more than 7 billion cubic feet of helium supplied gas to five helium plants during World War II, and fields now held as government reserves contain at least 2.5 billion cubic feet of helium.

Helium is separated from natural gas by cooling the gas to a temperature below the liquefaction point of its ordinary constituents, but above the liquefaction point of helium. The gas must first be




Helium production, 1926–37.

treated chemically, however, to remove small quantities of carbon dioxide and water vapor that would solidify in the low-temperature equipment and plug it. After that preliminary treatment, the natural gas is cooled to about – 300° F. in a high-pressure vessel. At that temperature the helium is still gaseous and is drawn from the top of the vessel; the other constituents flow from the bottom as a liquid. This liquid is vaporized in heat exchangers, where it chills the incoming natural gas, and then flows as residue natural gas into a pipe line for transportation to fuel-gas markets.



Helium plant at Amarillo, Texas, went into operation in 1929.

The low temperature is attained by expanding compressed and precooled gases, and liquid nitrogen is used as a refrigerating bath in the coldest part of the cycle. For final purification, the helium is compressed to 2,700 pounds per square inch, passed through a gas-liquefaction cycle, then through activated charcoal at the temperature of liquid nitrogen, and discharged into the high-pressure tank cars or cylinders in which it is shipped.

The entire process is continuous. Less than one minute is required to cool any given cubic foot of natural gas to the temperature of liquefaction, remove the helium, warm the residue gas to atmospheric temperature, and discharge it into the pipe line. A plant may process 30 million cubic feet, or about 700 tons, of natural gas in a day.

## HELIUM IN WORLD WAR I

The discovery of helium in natural gas opened the way for its production in quantity. In 1917 C. W. Seibel, now supervising engineer of the Bureau of Mines helium plants, was extracting small quantities of helium at a cost equivalent to about $2,000 a cubic foot. The late R. B. Moore suggested that helium might be produced in enough volume for use in airships in World War I. He was right, but the end of hostilities came before large-scale production could be achieved. In July 1917, funds were allotted by the War and Navy Departments to the Bureau of Mines for work on helium extraction, and three experimental plants were built to process gas from Petrolia field, Clay County, Texas. These plants produced about 200,000 cubic feet of helium, and 147,000 cubic feet was ready for shipment to France when the Armistice was signed.

Since the end of World War I, about 775 million cubic feet of helium have been recovered, and its

price at a helium plant is now about 1.5 cents a cubic foot. During World War II, 200,000 cubic feet of helium was produced in less than ten hours.

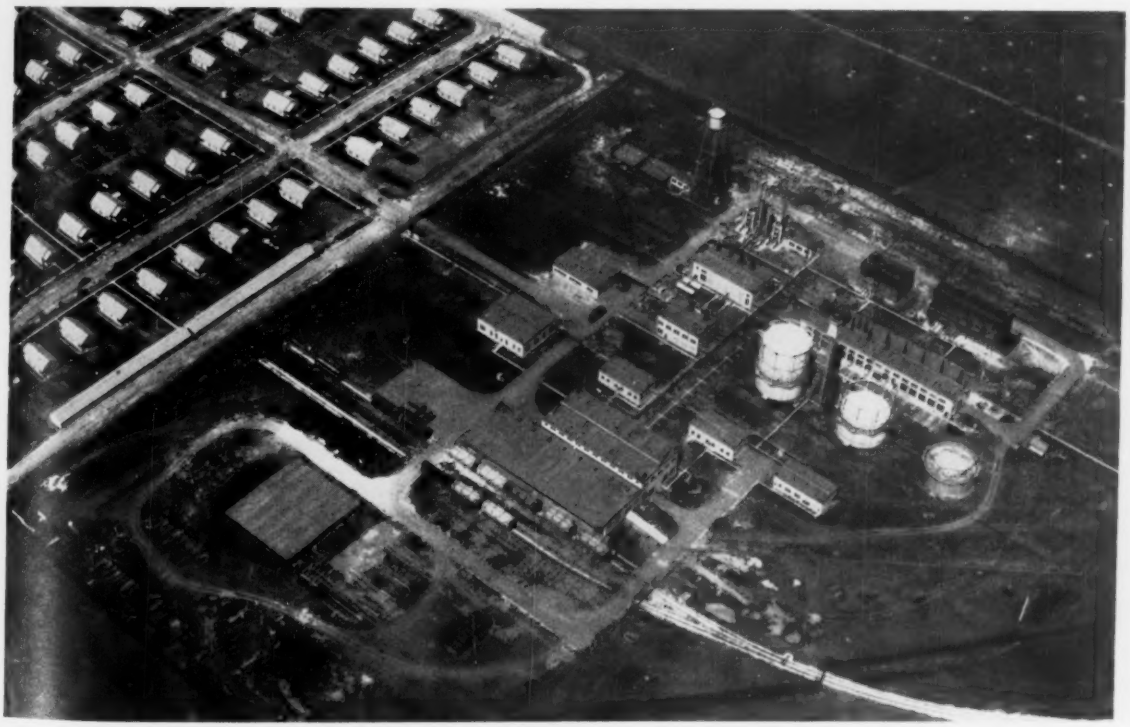
In December 1920, the Navy's C-7 was filled with helium at Bolling Field, and it made the first flight of a helium-filled ship. A full-scale helium plant, built at Fort Worth under the Navy's direction, began to operate in April 1921. On July 1, 1925, that plant and other government activities relating to helium production were placed by Congress under direction of the Bureau of Mines.

Helium production had its ups and downs during the first twelve years of the Bureau's administration. When the Bureau took charge of the Fort Worth plant, the *Shenandoah* and *Los Angeles* were flying, but the *Shenandoah* was lost two months later. Production was on a downward trend because the gas supply from Petrolia field to the Fort Worth plant was declining. Early in 1929, the Fort Worth plant was closed after producing approximately 46 million cubic feet of helium, and a new plant at Amarillo, Texas, was put into operation. The Amarillo plant receives gas with a helium content of 1.8 percent from the Cliffside field of Potter County, Texas, which was brought under full government control by acquisition of all gas rights in 50,000 acres. Annual production at Amarillo rose to about 15 million cubic feet in 1932, but after the loss of the *Akron* and *Macon* the demand dropped to about 5 million cubic feet a year in 1936 and 1937.

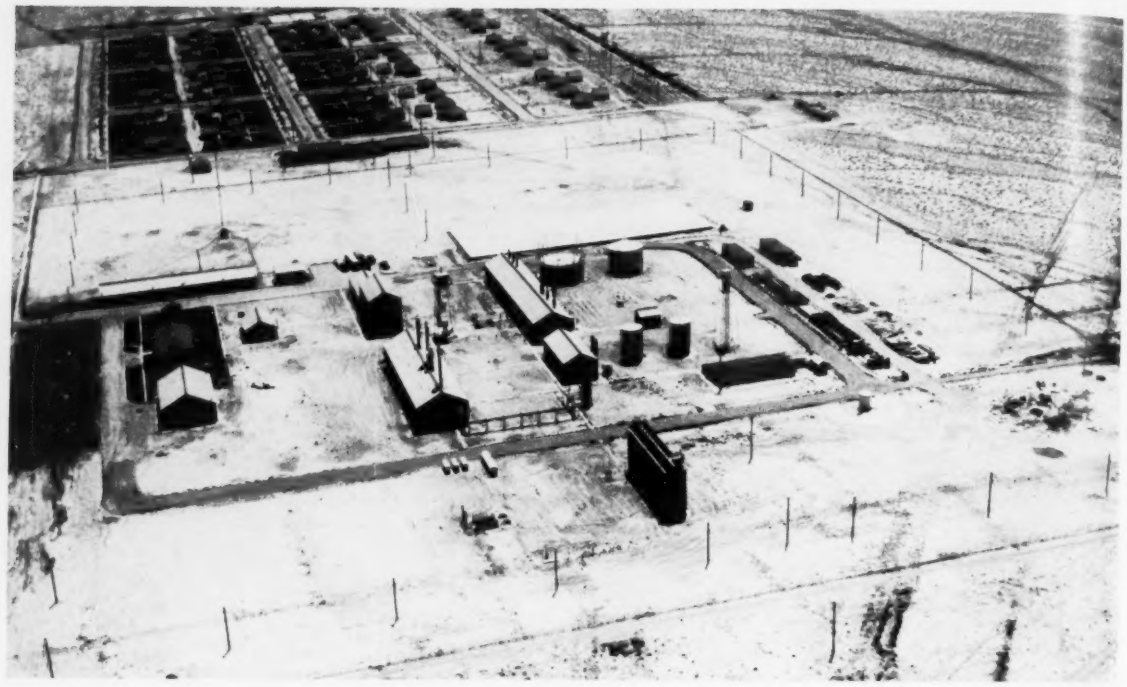
### HELIUM IN WORLD WAR II

When Germany invaded Poland in September 1939, the Amarillo plant was producing only about 0.5 million cubic feet a month, or about one quarter of its capacity, and its staff and crew had been reduced to a mere skeleton organization. As the war progressed in Europe, and after France capitulated in June 1940, the helium demand increased about 50 percent. In December of that year, the military services indicated that the volume required to meet their needs might exceed the capacity of the Amarillo plant. In February 1942, the Navy greatly increased its estimate of helium requirements, and three months later the February estimates were doubled when the Navy was authorized to increase its fleet of blimps to two hundred.

In spite of this rapid progression of estimates, the Bureau of Mines met every demand for helium on schedule. At no time were the Army and Navy forced to curtail activities because of insufficient helium production. When it became evident that the Amarillo plant would be inadequate, and funds were made available by the Congress, the Chan-



The Bureau of Mines Exell plant, thirty-two miles north of Amarillo, is the only helium plant now in operation.



Navajo helium plant at Shiprock, New Mexico, completed in 1944, is a Bureau of Mines stand-by plant.

ning area in the western part of the Texas Panhandle gas field was selected as the source of helium-bearing natural gas for a new plant, and Exell, Texas, on the Santa Fe Railroad about thirty-two miles north of Amarillo, was chosen as the plant location. The plant started to operate in March 1943, less than ten months after construction was started; and in July of that year, the Exell and Amarillo plants produced nearly 12,000,000 cubic feet of helium, although their combined rated capacity was only 8,000,000 cubic feet a month.

When the estimated demands rose to 20,000,000 cubic feet a month, additional funds were made available and new plants were constructed at Otis and Cunningham, Kansas, and at Shiprock, New Mexico. The Otis plant came into production in October 1943—nine and one-half months after the start of construction—and the Cunningham plant began to produce in January 1944. From then on the Bureau was able to meet the demand without serious strain on equipment and personnel.

By the time the Navajo plant at Shiprock was completed in March 1944, the German U-boats were under control, and other plants were meeting the helium demand. The Navajo plant was therefore given a test run to prove its efficiency in design and operation and then placed in stand-by status ready to start whenever its output might be needed. Contracts made by the Bureau with the Navajo Tribe of Indians and its lessees reserved a large deposit of gas of 7.5 percent helium content in the Rattlesnake field of San Juan County, New Mexico, to supply that plant.

In December 1943, the Army-Navy "E" Award was presented to the Amarillo and Exell plants for outstanding production of war materials, and the Otis plant received a similar award in March 1945. This recognition, and numerous statements by high military officials, emphasize the importance of helium production in World War II. In the government fiscal year 1944 the production was about twenty-two times that of the fiscal year 1939.

## HELIUM TODAY AND TOMORROW

Since Germany surrendered on May 7, 1945, the Exell plant has supplied most of the helium, and it is now the only plant in operation. Its output is about ten times the quantity that was being produced in 1938 and is meeting all governmental and private demands. A 2-inch helium pipe line connects the Exell plant with the Amarillo plant and Cliffside gas field, and when the Exell plant produces more helium than is needed to meet current demands the surplus is injected into the Cliffside field and stored for future use. The cost of producing this helium for conservation is very

low, because a steady plant output can be maintained with substantially the expenditure that would be required for a reduced rate of production. The cost of reclaiming the injected helium will also be low, because it can be recovered in the operation that will be required to extract the original helium content of the Cliffside gas.

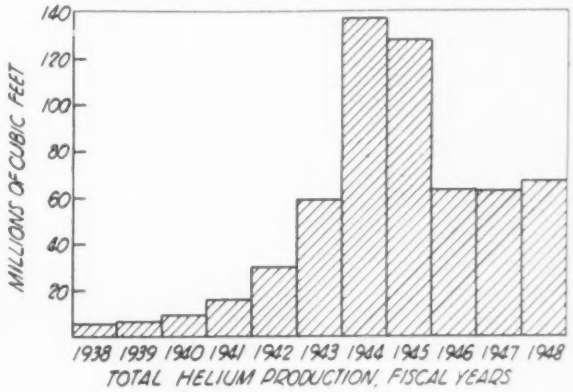
The Cunningham plant has been dismantled, but the Amarillo, Otis, and Navajo plants are available for operation whenever demands exceed the capacity of the Exell plant. Since the Amarillo and Navajo plants can be supplied from large reserves of helium-bearing gas now shut in under the Bureau's control, they represent "hole cards" to meet any future emergency demands for helium. The Amarillo plant is headquarters for the field administration of the Bureau's helium activities, including the helium research program. It also is used as a shipping point for some of the Exell plant's output, which is transported to the Amarillo plant through the 2-inch pipe line.

Helium is a unique element, with many extreme properties. At normal atmospheric pressure and 60° F., 1,000 cubic feet of helium will lift 65 5/6 pounds—92 2/3 percent as much as hydrogen. Helium diffuses more rapidly, flows through a hole faster, conducts heat better, and transmits sound at higher velocity than any other gas except hydrogen. It conducts electricity better than any gas except neon.

Helium has a lower solubility in water and other liquids, a lower refractive index, and a lower temperature of liquefaction than any other gas. The rate of ionization of helium when bombarded with electrons is slower than that for any other gas.

Helium is used as a lifting gas in airships and in observation, advertising, meteorological, and toy balloons. Rear Admiral C. E. Rosendahl has said that helium-filled blimps escorted 89,000 surface craft in World War II without loss of a single craft to enemy submarines, although 50,000 of them were in areas where U-boats were known to be present. The stratosphere balloon which carried men to the greatest height they have ever reached was filled with helium. Children have been given much pleasure and protected from injury through use of helium in toy balloons.

Helium-shielded arc welding, developed during the war so that magnesium alloys could be arc-welded successfully, has grown to assume a role of major importance in peacetime. Using helium as an inert gas shield around a tungsten electrode, industry has found that it can arc-weld aluminum, copper, stainless steel, titanium, and other metals without the use of flux or extensive prewelding preparation of the metals or alloys. The inertness of helium also is used to advantage in degassing molten metals, and in preventing oxidation or other chemical reactions in various metallurgical processes.




Helium production, 1938–48.

Helium is used with oxygen in breathing atmospheres for divers and caisson workers. Because of its low solubility in blood and body tissues, helium mitigates the painful and sometimes fatal caisson disease. This illness, known to divers as "the bends," results from the formation of nitrogen bubbles in the blood when men are removed from an atmosphere of compressed air to normal atmospheric conditions. Helium was used in the deepest dive ever made in a diving suit.

Because of its lightness and high rate of diffusion, helium is used with oxygen in breathing atmospheres for asthma patients and persons suffering with other respiratory difficulties. More oxygen can be breathed into the lungs with the same muscular effort.

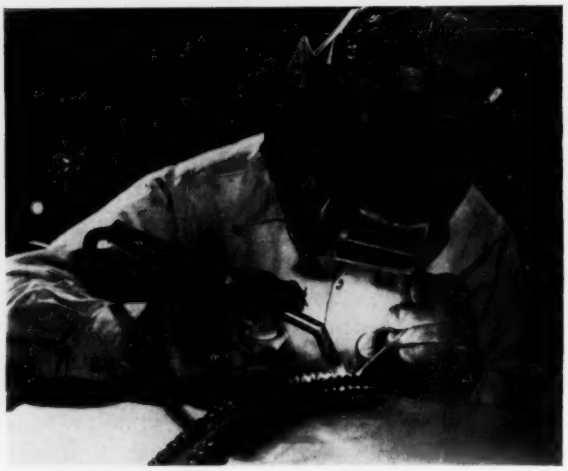
Because its refractive index is very nearly unity, helium is used to fill spaces between lenses in optical instruments. It is mixed with otherwise explosive anesthetics to make them safe in operating rooms. It is used as a tracer material in the detection of leaks in vacuum and pressure vessels, and to determine the underground movement of injected natural gas in oil and gas reservoirs.

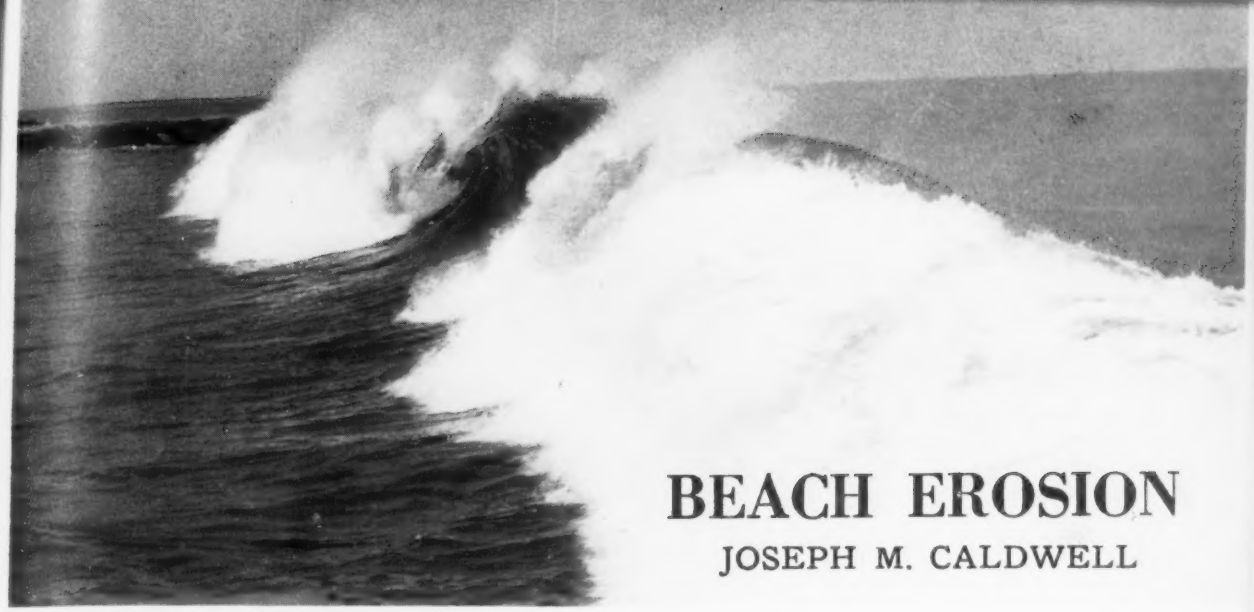
Helium is no longer a laboratory curiosity. It is produced in large quantities at high purity and reasonable cost. The Bureau of Mines believes that its growth as an industrial tool depends largely upon the rate at which knowledge concerning its properties, cost, and availability can be disseminated. To this end, the Bureau is conducting a modest research program aimed in three di-

rections: To make available to the American people the purest possible grade of helium at the lowest possible price; to develop known uses and open up new fields of usefulness for helium; and to assure, through conservation of known resources and a continuous search for new resources, that helium will be available to the American people for the longest possible time.

Thus helium, the sun gas, which has carried man into the air, helped him to dive deep into the sea, given pleasure to his children, relieved human suffering, and opened up new fields in science and industry, is now being produced in sufficient quantities to meet all present demands and is being studied and conserved to meet whatever needs the future may bring.

Welding magnesium sheet with a helium-shielded arc.





# BEACH EROSION

JOSEPH M. CALDWELL

*A graduate in electrical engineering of Mississippi State College, Mr. Caldwell has been chief since 1946 of the Laboratory Section, Engineering and Research Branch, of the Beach Erosion Board in Washington, D. C. Most of his previous experience was with the Waterways Experiment Station, Vicksburg, Mississippi. As a captain in the Army he did intelligence work in the Office of the Chief of Engineers.*

TO MILLIONS of Americans, the sand beaches of the Atlantic, the Pacific, the Gulf of Mexico, and the Great Lakes represent vacationland. Most of these people probably do not realize that a continual battle goes on to protect these beaches from the erosion caused by the almost ceaseless attack of the wind-generated waves working in conjunction with tides and currents.

A basic factor in beach erosion is the fact that in most localities a rather delicate balance exists between the forces tending to erode the beach by carrying the sand away and the forces tending to move sand onto the beach from other areas. Usually, both sets of forces—those of accretion and those of erosion—are present, and it is the difference between the two that determines whether a beach is eroding or building up (Fig. 1). Where the difference is slight, a fairly stable beach configuration is evident, although after a considerable period—say, fifteen or twenty years—the cumulative effect of the dominant force becomes apparent; where the difference is large, the beach may show radical changes in a year or two.

Any unusual conditions, whether natural or man-made, may upset the balance in such a way that what has been a very stable beach may quickly show significant erosion or accretion. For example, the hurricanes that at times sweep the Atlantic and Gulf coasts of the United States frequently produce pronounced changes on the affected beaches. The construction of the yacht harbor at Santa Barbara, California, so upset the balance in that area that the beaches for some ten miles to the east of the harbor were denuded of sand; sand is now pumped past the harbor periodically in order to restore and maintain these beaches.

The cumulative effect of wave action on a specific beach is somewhat dependent on the type of shoreline in the area. The shoreline of the United States is characterized by a diversity of shore forms, the New England shoreline being rather rugged, with cliffs and headlands fronting directly on the ocean and with rather short lengths of beaches caught between the headlands. The Atlantic shoreline from Long Island south, and the Gulf beaches, are mainly characterized by long, uniform beaches, with the adjacent topography lying only a few feet above high tide; often these beaches are in the form of a barrier beach separated from the mainland by a salt-water marsh or lagoon. The Pacific shoreline shows some of the characteristics of both types of shorelines, with long sweeping beaches broken by bold headlands.

The geologist recognizes the material forming the beaches as being largely derived directly from the rocks that originally formed the earth's crust. These rocks were of various chemical and mineral composition and physical characteristics and have gone through changes due to environment, so that many of them have been greatly altered.

For the moment, however, we are primarily interested in beaches, and we find that after all the weathering, frost action, glaciation, hydration, etc.

of these rocks and minerals there is only one type which exists in significant quantity and which is able to withstand nearly all the so-called destructive forces that nature can impose upon it. This is the mineral silicon dioxide, commonly known as quartz. The composition of practically all our beaches is predominantly quartz sand; small quantities of other rocks and minerals are usually present, but for the most part they have been ground to powder, gone into solution, or otherwise been removed from the picture.

The quartz sand reaches the beach environment by several means. Gravity may carry it from a cliff face into the zone of wave action. Winds may fashion dunes that migrate to the water's edge. Glaciers may leave moraines and drumlins along a coast, and in nearly every environment streams dump sandy detritus at their mouths. Once the sand has reached the coast, it is subject to further movement by a repetition of these transporting forces. Significantly, the effect of ocean waves on the spreading out and rearrangement of the beach components becomes a dominant factor when they come within reach of these waves.

## TYPES OF SHORELINES

The geomorphologist generally classifies the shoreline as being one of "submergence" or of "emergence" and goes on to show that this classification enables us to explain certain characteristics of the shoreline and predict what its future will be. For the most part these predictions are made on the basis of "geological" time and involve time intervals of the order of hundreds or thousands of years.

The terms "submergence" and "emergence" are more or less self-explanatory. A shoreline of submergence is one where the land mass has subsided with respect to mean sea level. In this case valleys are submerged, and interstream ridges rise sharply above irregular embayments, forming rocky headlands that are faced with wave-cut benches, with intermittent stretches of beaches caught between the headlands. The cumulative attack of waves and weather on these rugged shorelines wears away the irregularities, and will ultimately bring about a fairly straight shoreline characterized by beaches backed by a prominent cliff line. The New England coast is an excellent example of a shoreline of submergence in an early stage, whereas the Oregon coast is a more maturely developed shoreline of submergence.

The term "shoreline of emergence" signifies that the beach is rising with respect to mean sea level. As most underwater areas are fairly level, emergence exposes a gently sloping marine plane, upon which waves, breaking in water 10–30 feet deep, will pile up a barrier beach or offshore bar, leaving a lagoon between the barrier and the mainland. These barrier beaches are commonly cut through at irregular intervals by tidal inlets which connect the ocean and the lagoon. The shoreline of New Jersey is an example of a shoreline of emergence. The mature stage of a shoreline of emergence is reached when the lagoon has been filled, partly by the barrier beach being forced back into it and partly by normal sedimentation in which clastic debris and vegetation may take part.

## WAVE ACTION

Various forces act upon the beach material, a dominant force being the wind-generated ocean waves. The height of waves generated over the open ocean by the wind is controlled by three factors: the wind velocity, the duration of the wind, and the "fetch." The fetch is the length of

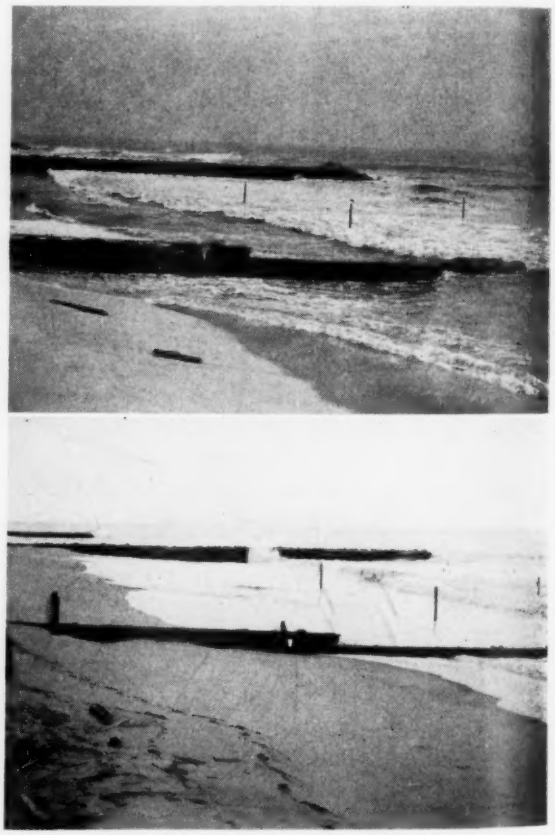


FIG. 1. Two views of shoreline near Long Branch, N. J., showing change in beach elevation over period of one year. This accretion represents more or less normal fluctuation in the beach elevation from year to year.

the stretch of open water actually in contact with a specific wind development.

Once these waves have been generated by a wind disturbance, they may leave the area of the disturbance and travel for hundreds or even thousands of miles before being interrupted by a land mass. In fact, most of the waves seen along our ocean beaches have been generated by distant storms.

There are several distinct classifications of water waves, among them progressive, stationary, and solitary waves. So far as beach action is concerned, we shall confine this portion of our discussion to a description of progressive oscillatory waves. These are waves that show a progressive movement of successive crests in a single direction, whereas the water particles themselves move in an essentially circular path when in deep water. In effect, this means that the wave form moves forward, but there is little or no progressive forward movement of the water particles. This is easily demonstrated by the fact that a cork thrown on the surface of the sea oscillates back and forth in the area of introduction although the wave crests move through the area in rapid succession. The waves themselves are described by the "length" from crest to crest, the "height" from trough to crest, and the "period," which is the time interval between the arrival of successive crests at a stationary point.

As the wave moves into shallow water, the bottom begins to affect the form and mechanics of the wave. First, the circular paths of the water particles are gradually changed into elliptical paths, and the height and length of the wave are altered somewhat. Finally, the wave reaches a depth so shallow that the mechanics of the fluid motion make it impossible to transmit the oscillatory wave form any further; at this point the wave combs over and breaks.

In order to obtain a clear picture of these ocean waves, let us consider them from the time of their inception in the open sea until they destroy themselves by breaking on some distant shore. Suppose a meteorological disturbance over the North Atlantic generates a wind with a velocity of 26 knots blowing for some twenty-four hours over a fetch of 300 nautical miles. Empirical relations that have been established show that these conditions would generate a train of waves that would leave the storm area with a height of about 15 feet, a length of about 300 feet, and a period of about 7.5 seconds. One way of describing such waves is by length-height (L/H), or steepness, ratio. In the present instance, the ratio would be 20. The mechanics of the fluid make it impossible to get a L/H ratio of less than about 7.

As the waves leave the generating area they begin to lose energy, the principal loss being due to atmospheric resistance. This results in a change in the shape of the average wave, specifically a decrease in height and an increase in length. Let us suppose that the 15-foot waves in the above example leave the generating area and travel over some 2,000 miles of open water before reaching a shore. This 2,000 miles is called the "decay distance," and studies show that at the end of this decay distance the selected waves will have decreased in height to 2.5 feet, increased in length to 1,300 feet, and lengthened in period to 16 seconds. The waves have now become low swells, which are the waves usually to be seen on our beaches during fair-weather periods.

The L/H ratio of these waves has now become 520. A large L/H ratio is characteristic of swells; in fact, this L/H ratio is one method by which ocean waves are classified. For general purposes, we can assume that L/H ratios between about 7 and 35 characterize storm waves (waves in or near their generating area), ratios between about 35 and 70 characterize intermediate waves, and L/H ratios greater than 70 characterize well-developed swells.

During World War II, work on the prediction of waves received considerable impetus owing to the many military amphibious operations that involved the use of small craft in open waters. Studies were made to correlate wave height and wave length as a function of the velocity, duration, and fetch of the wind. The change in wave characteristics during travel from the storm area to the beach was also studied. As a result of these studies, it has been possible to prepare charts showing the interrelation of these factors (Figs. 2, 3).

If we study one of the 2.5-foot swells as it comes into shallow water, we find that, so far as the wave is concerned, the water becomes shallow when the depth is equal to about one half the wave length. At this depth we say that the wave "feels" the bottom, and the motion and form of the wave start to adjust themselves to this new condition. Generally speaking, the effect is to increase the height and decrease the length. Also, the internal motion of the water particles changes from circular to elliptical, with a noticeable increase in the velocities at the bottom. In fact, these bottom velocities finally become of sufficient magnitude to roll the sand particles back and forth on the bottom, sand ripple formations result, and some of the sand may be thrown temporarily into suspen-

sion. Once the sand particles are in motion, any alongshore currents may cause a corresponding alongshore movement of the sand particles.

As the wave moves into even shallower water, it finally reaches a depth where the wave crest can no longer be supported, and the wave breaks. This breaking is accompanied by great internal turbulence and causes large quantities of sand

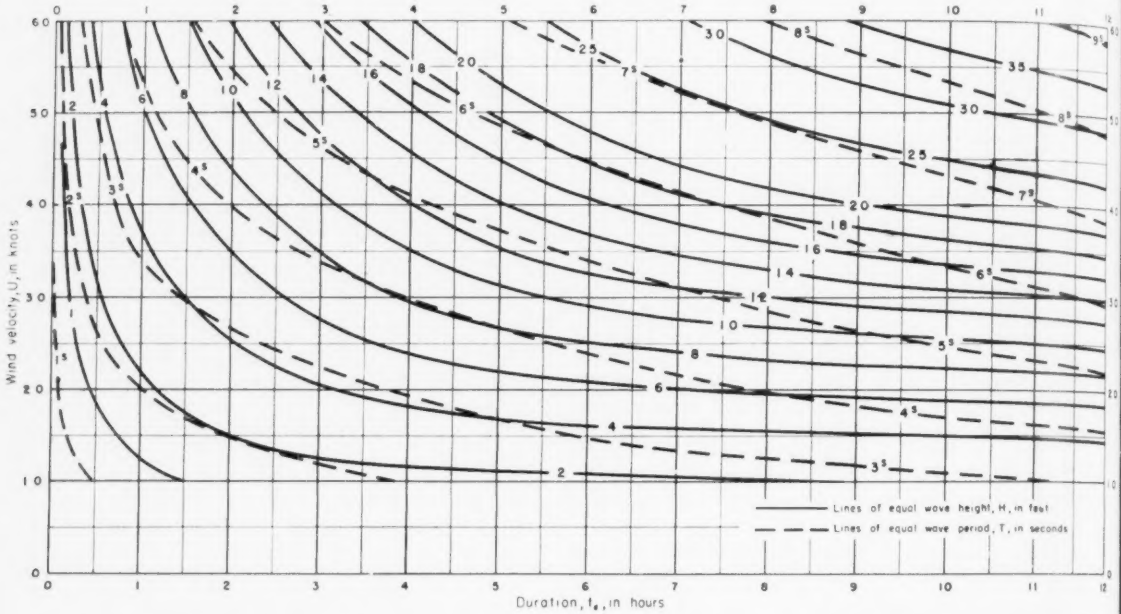



FIG. 2. Wave height and period as functions of short duration of wind and wind velocity. (Chart prepared by the University of California for the Bureau of Ships; used by courtesy of the *Bulletin of the Beach Erosion Board.*)

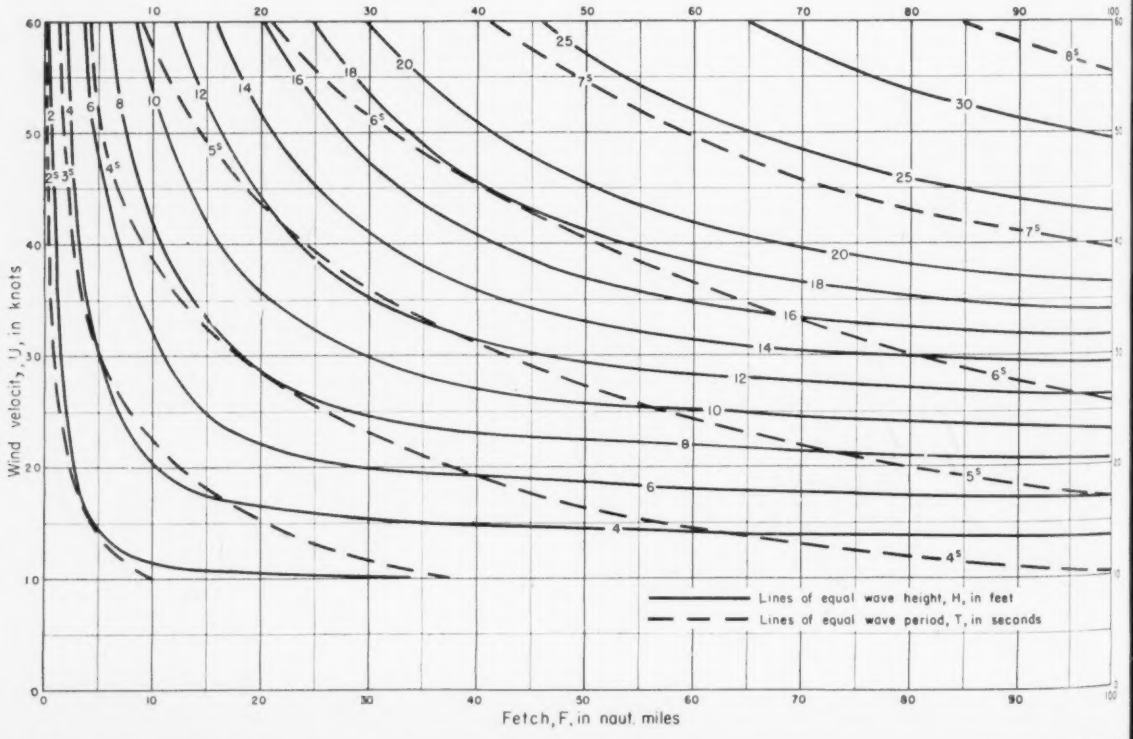



FIG. 3. Wave height and period as functions of short fetch and wind velocity. (Chart prepared by the University of California for the Bureau of Ships and used by courtesy of the *Bulletin of the Beach Erosion Board.*)

to be thrown into suspension. This breaker zone is generally the most active zone from the standpoint of action of the sand particles forming the beach. Hydrodynamic relations show that the 2.5-foot swell will have increased in height to about 5 feet by the time it reaches a water depth of 9 feet, at which depth it will break. On gently sloping beaches, the wave may re-form, only to break again in even shallower water. On the steeper beaches, the broken mass of water will rush up on the beach and return to the sea as backwash.

In nature waves do not travel as simple, uniform wave trains. The picture is usually rather confused, with what might be described as a spectrum of waves present, some high, some low, and of varying length. In deep water the longer waves travel the faster and overtake and move through the shorter waves. Descriptions of the state of the sea usually include only the dominant waves present, whereas an accurate description would involve a breakdown into all types.

A very important feature of wave action on beaches is angle of approach. In deep water waves may approach a beach at almost any angle. As they move into shallow water, however, they are refracted in such a way that they tend to adjust their crests parallel to the bottom contours. Thus, a wave approaching in deep water at an angle of 45° to the shore may have an angularity of only 5° or so by the time it finally breaks on the beach. Even this slight residual angularity generally has the effect of setting up a littoral current alongshore in the direction of the angularity. This littoral current, in turn, frequently becomes a dominant feature in beach erosion and accretion.

It might be well to mention the contrasting action of storm waves and swells on the beaches. Generally speaking, the swells tend to move sand from offshore and deposit it on the beach; on the other hand, waves resulting from local storms tend to tear the beach down by removing sand and leaving it in submerged bars offshore. (These two statements are rather generalized; other factors, such as beach slope and sand size, could invalidate them somewhat.)

## TIDES

Tidal action also influences the characteristics of a given beach in that, as it rises and falls, the tide shifts the zone of wave attack up and down the beach. The tide may also set up tidal currents that can affect the movement of sand on the beaches.

The magnitude of rise and fall of the tide—i.e., the tide range—varies from day to day at any given locality; it varies noticeably from place to place around the shores of the United States, averaging 4.4 feet at New York, 1.3 at Key West, 4.2 at San Diego, and 7.6 feet at Seattle. In general, the tide follows the moon, and there are two high tides and two low tides each lunar day of 24 hours 50 minutes; thus highs and lows follow each other at intervals of about 6 hours 12 minutes. There are some exceptions to this, particularly along the Gulf Coast in the vicinity of Pensacola, Florida, where there is usually only one period of high and one of low water in the lunar day of 24 hours 50 minutes. Of course the tides are also influenced by the sun, although the tide-producing potential of the moon is roughly about 2.25 times that of the sun.

The principal variation in the tide is due to the phase of the moon with respect to the sun. Thus, at times of full moon and new moon, the sun and the moon are working together and produce a series of tides of relatively large range, called spring tides, which may have a range of 1.5 times the average. At times of the first and third quarters of the moon, the sun and moon are working in opposition to each other and produce a series of tides of relatively small range, called neap tides. Spring and neap tides follow each other at intervals of about 7 1/3 days. It is recognized that if storm waves reach the shore coincident with high water during a spring tide, the potentialities for damage to the beach and its structures are much greater than usual.

Tidal currents may generally be seen along the coasts only in the vicinity of bays, estuaries, or inlets. The rise and fall of the tide produces a flood and ebb of the current filling and emptying the estuary. This may reach sufficient magnitude in the vicinity of the estuary to cause erosion by its own action. The effect of the current is felt over a much larger area, however, where the currents are too small to effect the movement of the beach sand by themselves but where they can produce a significant action by working in conjunction with the waves breaking on the beach. Some streams and rivers have so much fresh-water discharge that this is more important than the tidal flow, and the fresh-water currents may affect the beach in the same manner as the ebb flow of the tide.

## SAND MOVEMENT

The net effect of the forces described is to produce a beach that may be accreting or eroding, may show cyclic or seasonal changes, and is seldom if ever stable. In effect, the entire beach surface

is generally in motion. It might be pictured as a river of sand whose direction and velocity are determined by the character of the forces impressed upon it in the form of winds, waves, and currents.

Possibly the critical point to remember is the fact that once a sand grain is put into suspension, the slightest movement of the surrounding water will produce a corresponding movement of the sand particle. As long as the particle remains in contact with the bottom, currents of one foot per second or more will be required to move even the fine sand. Almost unceasing wave action on the beaches, however, continually keeps a substantial amount of sand in suspension.

If the waves approach the beach from the perpendicular, the sand movement is essentially an oscillation back and forth of the particles, with little progressive movement parallel to the shore. If even a slight littoral current is present, however, the movement of material can be relatively great. As already pointed out, these littoral currents can be generated by waves approaching at an angle to the shore, by tidal currents, or by the fresh-water discharge of near-by rivers.

The distinction between the littoral current and the littoral drift should be noted. The current is the movement of the water mass; the drift, the movement of the solid particles. The coast of Santa Monica Bay in the vicinity of Santa Monica, California, is considered to have a fairly rich littoral drift, the net direction of drift being from north to south. Here the average net rate of drift is some 800 cubic yards per day, or a rate of some 300,000 cubic yards per year. A rate of 50–100 cubic yards per day is usually spoken of as a lean drift, although the terms "rich" and "lean" are used relatively.

A

B

C

FIG. 4. Views of Redondo Beach, Calif., showing severe erosion resulting from construction of yacht harbor breakwater. (*a*) Condition of beach immediately prior to completion of breakwater. (*b*) Condition seventeen months later. Note top of theatre in upper right background. (*c*) Condition of beach six years later. Erosion has wiped out block of buildings between the theatre and original shoreline.

On a beach where the drift is dominantly in one direction, it can readily be seen that any interruption in this drift may produce significant changes in the adjacent beaches. Suppose an impermeable structure such as a groin is built out from such a beach. The result will be an erosion of the beach downdrift from the structure and an accretion of the beach updrift. In cases where a rich littoral drift exists, this erosion-accretion picture will probably develop very rapidly, and wherever this erosion takes place in a well-developed commercial or residential area severe damage may result in a period of three or four years (Fig. 4). Of course, once the sand-impounding capacity of the structure has been reached, the flow of sand past the structure is re-established.

Frequently, we find that the natural conditions at a beach are not in stable adjustment and that progressive erosion of the beach is under way. In such cases, the eroding condition can sometimes be arrested by the construction of a groin field to check the natural rate of removal of material from the beach. Even under these conditions consideration must be given to adverse effects downdrift from the groin field. Groins of many lengths, shapes, and sizes have been utilized by various agencies in an attempt to discover the most effective type.

The fact has been mentioned that, generally speaking, waves from a local storm tend to tear the beach down, whereas swells from distant storms tend to build it up. This alternate building up and tearing down of the beaches usually causes a shifting back and forth of the water line. In well-developed areas this shifting may be undesirable, and in some cases cannot be tolerated. To forestall such shifting of the water line, particularly its shifting shoreward, reliance is sometimes placed on the construction of a beach bulkhead placed a short distance shoreward of, or near, the mean water line. These bulkheads, or seawalls, are usually of heavy construction, and some types have their seaward toe protected by installations of large stone or rock. A tendency to economize on these designs and a lack of understanding of the potential destructiveness of wave action have resulted in many costly failures of this type of protection. A workable solution is often the building of a beach bulkhead in combination with a groin field.

In addition to the various forces previously described, wind blowing over the beach can be an effective agent in moving the sand, and should always be considered when making a study of a specific locality. The large sand dunes along many of our coasts testify to the effectiveness of the wind.

In their attack on our shores, the waves of the sea present a worthy foe to tax the knowledge and ingenuity of our engineers and scientists. The agency charged with handling Federal interests in beach protection, including cooperation with states and municipalities, is the Beach Erosion Board of the Corps of Engineers, Department of the Army. Many of the states with beach erosion problems have, in addition, special agencies set up within the state government to deal with their own problems.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# THE GREAT EXPERIMENT

EARL P. STEVENSON

*A graduate of MIT in chemistry in 1918, Mr. Stevenson became director of research for Arthur D. Little, Inc., the following year. He has been president since 1935. His article is based on an address given at Wesleyan University, April 23, 1949.*

IT IS not sufficient today merely to define science as a body of knowledge and a method of apprehending experience. Science, and its expression in technology, has entered too deeply into the consciousness of the layman and into the formation of his daily life—especially here in America. Science is a national concept and one of as much concern to every citizen as the state of agriculture or industry. The recent world war, as the public well knows, was fought not only with men's bodies and lives on the fronts, but with the brain of the scientist and the experience of the engineer. It was Hitler's boast, at the beginning of the war when events went so swimmingly for the German armies, that to keep one man fighting at the front two men worked in the laboratories and factories at home. It is certainly in some measure due to the fact that we in America were able to increase that ratio manyfold that the tide of war turned for us.

The atomic bomb was but one contribution of the scientist during the war, although naturally a particularly impressive and terrible one. Dr. Robert Oppenheimer, whose name we instinctively associate with the development of the atomic bomb, has himself laid far more stress upon the importance of the development of radar. But it is no wonder that, as Lyman Bryson has said in *Science and Freedom*, ". . . there is now, in the superficial layers of the public mind, a momentary revulsion against science." It is admittedly difficult for the average citizen to understand the language and even the mentality of the scientist. He must judge the scientist by what the scientist has produced: the atomic bomb. And contemplation of the atomic bomb does not summon as quickly to mind that question tapped out by Samuel Finley Breese Morse, introducing an earlier power to the world with "What hath God wrought?"

## I

In the face of this public concern, the Federal government is engaged in a great experiment—the official underwriting of scientific research. Those who follow the progress of bills before the Congress are no doubt cognizant of the fact that a National Science Foundation Bill has, after a stormy passage, been approved by the Senate. This bill will

> create a foundation to serve as a permanent central scientific agency of the Federal Government and both specifically [authorizes] the foundation to support financially and promote research in the fundamental sciences, national defense, medicine and health, to expand the nation's scientific talent through the granting of scholarships and fellowships, and to foster the interchange of scientific information among scientists. [It will] provide for an organizational structure for the foundation (*a*) which will permit the maximum participation by the Nation's scientists in formulating the Foundation's program, both as full-time Government employees and as part-time consultants, and (*b*) which will fix responsibility for the execution of the program in officials directly responsible to the President and to the Congress.

The Foundation will be an independent agency of the Federal government, and will be managed by an administrator appointed by the President. The administrator will appoint a director to head each of eight to ten divisions of the Foundation, and he will consult with a National Science Board whose members will be appointed by the President to three-year terms of office. And with the establishment of the National Science Foundation the distrustful American public itself will embark on a science program.

The recognition of science as an essential element in national life has been slow but steady. It is difficult nowadays to realize that for our forefathers theories and facts of science—and engineering—which we take for granted simply did not exist. When James Watt and his partner, Matthew Bolton, first set up a small bead factory, they found the river they were using for power inadequate, whereupon they bought a steam pumping engine—then a very new device—*to pump the water upstream from below the dam*, so that they might use the water power twice over. That seems to us today absurd. We would harness the steam engine to a shaft and utilize the engine's power directly. We cannot realize that the mechanical movements

essential to the transmission of power from engine to work were unknown barely a century ago.

The early dabblers in science, the alchemists of the Middle Ages, seem to have been motivated in part by the idea that their work would lead to something of immediate practical value. Bacon visualized the "House of Salomon" for the investigation of nature by observation and experiment to attain "the knowledge of causes and secret motions of things, and enlarging of the bounds of Human Empire, to the effecting of all things possible." Yet we have had to wait for the turn of this century to find established the present relationship between science and technology alone. The following story has been told of the great mathematician Hilbert, who

> would have liked, had the world let him, to have thought of his science as something independent of worldly vicissitudes. Hilbert had a colleague, an equally eminent mathematician, Felix Klein, who was certainly aware, if not of the dependence of science generally on society, at least of the dependence of mathematics on the physical sciences which nourish it and give it application. Klein used to take some of his students to meet once a year with the engineers of the Technical High School in Hanover. One year he was ill, and asked Hilbert to go in his stead, and urged him, in the little talk that he would give, to try to refute the then prevalent notion that there was a basic hostility between science and technology. Hilbert promised to do so; but when the time came a magnificent absent-mindedness led him instead to speak his own mind: "One hears a good deal nowadays of the hostility between science and technology. I don't think that is true, gentlemen. I am quite sure that it isn't true, gentlemen. It almost certainly isn't true. It really can't be true. *Sie haben ja gar nichts mit einander zu tun.* They have nothing whatever to do with one another."

The war did much to improve the working relations between the scientist and the engineer. In many instances each was forced to delve deeply into the domain of the other. The gain in mutual respect was reflected in effective teamwork and accelerated programs. Heretofore neglected areas of scientific knowledge were searched for data essential to a difficult design problem—even anthropologists were employed by one engineering group!

Following World War I, the expenditure of government funds on various research projects had greatly increased along with the growth of science and technology in this country. Such agencies as the Bureau of Standards, Naval Research Laboratory, Department of Agriculture, Bureau of Mines—to mention only a few—had been recognized for their contributions to science and technology. The trend toward government participation in scientific research was accelerated by the experience of this country during World War II in mobilizing scientific and engineering talents for national defense. It was realized in 1940 that there was not enough time to expand the existing government research agencies to the extent demanded by the emergency. The only alternative was to make effective use of the facilities existing in industry, universities, endowed institutions, and various government laboratories. Thus was born the Office of Scientific Research and Development, whose mission it was to work through contracts administered by committees of experts in the various fields. Thus there came into being the Radar Laboratory at MIT, which recruited its personnel, starting with a local nucleus, from universities and industry throughout the country. Other large centralized groups were also organized—rockets at the California Institute of Technology—atomic weapons at the University of Chicago—high explosives at the Bruceton Laboratory of the Bureau of Mines—proximity fuses at Johns Hopkins. In most instances the various divisions of OSRD worked through widely scattered facilities, using men and equipment immediately available and integrating various projects into an organized program through small administrative groups.

The system worked beyond the fondest hopes of those responsible for the idea in the beginning. What more natural than that there would be a movement started even before the close of the war to perpetuate this device in the interest of peace?

The first bill toward the establishment of a National Science Foundation was drafted in response to a request of President Roosevelt's, made in November 1944, to formulate a postwar plan for scientific research. When it was first proposed, the role in, and importance of, science to our national life seemed self-evident, and in accord with the benevolent atmosphere of cooperation which marked the years of the war and the early months of the United Nations Organization. There have, however, been subsequent clashes along the way between the thinking of the politicians and the scientists. The necessary legislation was once enacted, in 1947, only to meet the veto of the President. A compromise was then reached in committee during the Eightieth Congress, and in its present form the bill seems acceptable to both factions.

In 1947 the President appointed his Scientific Research Board, comprising several members of his Cabinet and the heads of the various government agencies most interested in research matters, such as the chairmen of the Atomic Energy Commission, the National Advisory Committee on Aeronautics, and the Federal Communications

Commission, under the general chairmanship of Dr. John R. Steelman. Their report, *Science and Public Policy*, should be required reading for alert citizens as well as for scientists. The report indicates the surprising extent to which the Federal government has already participated in research and development projects of national significance. "In the five years from 1941 to 1945 the nation spent $3,000,000,000 for these purposes, almost all of it going for the development work on implements of war. About 83% of the total cost of this large program was financed by the Federal government." Exclusive of the large expenditures allotted to the Atomic Energy Commission, the government spent approximately $625,000,000 in 1947, of which $500,000,000 was allocated to the Navy and War Departments, and of this amount 80 percent was spent through contracts with industrial laboratories, endowed research institutions such as Battelle and the Armour Foundation, and educational institutions. Apart from military services and the National Advisory Committee on Aeronautics (NACA), the largest Federal spenders are the Departments of Agriculture and Interior, each with an annual budget of around $30,000,000 for research. The nation's postwar budget for research and development in 1947 reached the highest point in our history—more than $1,100,000,000, excluding the Atomic Energy Commission's budget of about $600,000,000. Industry's participation in this program is estimated at $450,000,000. Thus, in the partnership we are about to see established between government and industry in research and development, the government is already the controlling partner in point of dollar contributions. On the other hand, the facilities, excepting again the Atomic Energy Commission, are predominantly in the hands of industry.

Thus in the interim between the first proposal of a National Science Foundation, to extend and expand the wartime cooperation among government, industry, and science, and now when it seems about to become law, neither science nor the government has stood still. Many of the facilities upon which the Foundation would have depended have already been pre-empted by other programs. Each of the three departments of the National Military Establishment—Army, Navy, and Air Force—has its own research plan and program, coordinated by the Research and Development Board, of which Dr. Karl Compton is now the head. Yet to some, this "unholy alliance" of military men and scientists is a fearsome state of affairs, and has been accepted only as a makeshift arrangement pending the final resolution of the problem in the National Science Foundation.

## II

The nearness of the National Science Foundation Bill to enactment by the Congress raises in the minds of scientist and layman alike most pertinent questions. Will the Foundation become subject to the vagaries of politics? What will be its relationship to other agencies of the government? Will it prove its value in the integration and development of essential basic research in this country? And—will it prove as valuable (or more valuable) to the public weal as research supported by private industry? (NOTE: Whoever has read the published accounts of German experiments in atomic energy under Hitler will have noted with apprehension that the Nazi government refused to make funds or personnel or equipment available for research where it could see no *immediate* gain. Granted, it was a time of dire emergency; granted, also, the government had supreme and unrestricted power over the means to research. But would this not undoubtedly be the instinct of a government which has to answer openly and directly to the public, and which has to maintain itself in office politically? A "four-year mandate" would not necessarily imply that the government could afford public criticism of expenditures as an individual or a business organization might.)

The majority of these questions will only be answered by time and personalities. If the Foundation is supported with intelligence and confidence; if it is truly allowed to be a coordinating body of industry, government, and science; if it is as fully subject to active support and active condemnation by an enlightened citizenry as any department of state or commerce—it may well become a truly great experiment in American government. The last condition deserves, perhaps, closer examination, and it might be helpful to call to mind some of the advances of recent years brought about by private industry engaged in scientific research.

American research and industry have a long tradition of interdependence. In the beginning, research efforts on the part of business were sporadic and unorganized. They were characterized by a desire on the part of keen-eyed merchants with spare capital to "get hold of a good idea" and build it into a new business of quick profits. An invention was less important for any fundamental scientific value it might have than for its suitability for exploitation. Gradually, certain groups of business-

men became convinced of the desirability of sponsoring a regular program to produce and support invention along the lines most necessary to them. They fixed their eye on a longer and bigger business chance, so to speak. It was about this time (1890) that George Eastman was writing to an associate in London,

> It will not be long before your firm will need a practical chemist . . . the best way is to make application to the Professor of Chemistry in some good technical school and have him recommend two or three first-class boys. You can . . . take your choice. . . . If he is any good he will be the most profitable man you can hire.

The Aluminum Company of America furnishes at this time one of the first instances of a company whose business was not only made possible by the perfection of a scientific method of treating metals, but which from its inception as a company insisted on the maintenance of a research laboratory as an integral part of the business organization.

But perhaps the most clear-cut example of what private industry can do with sponsored research—and one of the best examples of what a business has been *willing* to do—is that of the amazing petroleum industry.

The discovery of petroleum in Pennsylvania in August 1859 brought to an early decline the age-old industry of whaling: a fraction of petroleum—kerosene—was more than an acceptable substitute for whale oil. Fortunately, the pools of petroleum first drilled contained a substantial quantity of the kerosene fraction, and a minimum amount of the lighter oils which were, in the beginning, destroyed for lack of knowledge of the uses to which they could be put. Work on the internal-combustion engine, which was to provide an outlet for the lighter oil fraction, proceeded so swiftly, however, that by the turn of the century it began to appear that the light oil fractions obtainable would not long satisfy the demand for them. By 1910 demand for gasoline began to approach the amount naturally available from crude oil.

Petroleum, it might be explained, is a mixture of thousands of different hydrocarbon molecules of different sizes and shapes. Hydrocarbons with 5–10 carbon atoms have the volatility and other properties required of gasoline; those with 11–15 constitute the kerosene fraction; 16–23, domestic fuel oil; still heavier molecules comprise the lubricants, heavy fuel oil, and asphalt. Early refining of Mid-Continent crude oil consisted in roughly separating these molecular species into groups or fractions such as kerosene or gasoline, leaving around 70 percent residual for sale as gas oil or in competition with coal as a fuel.

Dr. Burton and his two assistants, who in 1909 constituted the research department of the Standard Oil Company of Indiana, sensed the approaching dilemma. They began to experiment with methods of cracking the larger hydrocarbon molecules, and finally devised the process of heating the gas-oil fraction in direct-fired cylindrical stills about 8 feet in diameter and 30 feet long, to a pressure of 75 pounds and to a temperature of 730°. By this means it was possible to double the yield of gasoline.

A comparatively rapid commercial development followed. Many companies took out patent licenses, and hundreds of Burton stills were installed. Since then, tens of millions of dollars have been spent in the continuing study of the reactions involved in cracking and re-forming the hydrocarbon molecules naturally occurring in crude oil.

The discovery that internal-combustion engines could operate at a higher compression ratio, and hence more efficiently on these synthetic fuels, stimulated research toward improving their quality. Because it was sensed that this behavior was due to the structure of the hydrocarbon molecules, basic research programs were instituted to study this structure. These programs culminated in the development of the modern catalytic cracking plants which so conspicuously adorn the sky lines of a modern refinery.

In the wake of these developments in petroleum fuels there has come into being, in the past twenty years, a petroleum chemical industry producing annually articles valued commercially at $600,000,000. These products of the petroleum chemical industry supply as well many basic needs of our increasingly complex economy. Without certain of these chemical compounds, for example, the synthetic rubber program of World War II would have been impossible, and America, dependent upon rubber-tired transportation, would have come to a slow stop.

The results of research on cracking, while profoundly affecting the direction and extent of technological development in this country during the past three decades, have been of social and economic significance. From 1918 to 1947, the energy consumption of this country increased enormously. Of that total increase in energy consumption, including heat for homes, petroleum and natural gas represent 95 percent, water power 5 percent, and coal has remained at its old level.

Automobiles, trucks, buses, tractors, and air-

planes could never have expanded to the present number without the more than doubling of the country's gasoline supply through cracking. The total vehicular horsepower is now over 3 billion as compared with 70 million in all central-power stations. The output of food per farm worker has been increased by 50 percent through the expansion of gasoline-powered farm equipment in the past twelve years. The horse population has been reduced by about 10 million since 1928, so that we can now feed 40 million more people. This alone means that we can supply Europe with the amount of food needed to exceed the mere subsistence levels at which European civilization would slowly but surely perish. By supplying the British Spitfires during the Battle of Britain with synthetic 100-octane gasoline, and thus with a margin of superiority over German planes, we presumed to direct the course of history. Through our high per capita energy rating we are now able to accept our obligations for these acts, in implementing the Marshall Plan. Each of us in America is served on the average by an amount of energy equivalent to that furnished in ancient times by thirty slaves.

In reviewing the research achievements of the petroleum industry, Dr. Robert E. Wilson, chairman of the Board of Standard Oil Company (Indiana), recently summarized his findings in an address entitled "Research on a Single Reaction and its Social Effects." He said:

> But how did all these beneficial social effects come to pass? Were they the result of some fine central planning and ordering of our industry and our national economy? Far from it. They resulted from the natural operation of the hope-of-profit incentive, teamed up with science and technology. . . . No Government subsidies were asked or needed. Indeed the industries dependent upon cracking have paid billions of dollars in taxes and made employment for millions of men. They are taking a substantial share of the output of our technical schools and are supporting an increasing amount of basic research in our universities. True, the individuals and companies who pioneered in cracking profited thereby—if they had not, cracking would never have gone forward. As with all successful inventions, however, these individual profits were but a drop in the bucket to the enormous social benefits which flowed from them.

## III

And now to look at the other side: Can a case be made out for government-supported and -planned research? It is argued that the greater the complexity of our needs, the greater dependence upon fundamental knowledge for advances, the inevitable specialization of our scientists, the higher cost of research, and the need of insuring national security in a military sense can only be met by further expanding the role of government. Proponents cite the experience of the Office of Scientific Research and Development in mobilizing and directing the technical manpower of the nation during World War II. In the instance of the Manhattan District they present the strongest case. All factors combine to support the Atomic Energy Act of 1946 as providing the only possible means under present-day world conditions for the development of nuclear science and engineering. It remains, however, to be demonstrated that an all-out government-planned and -supported program can match the achievements that can be cited from the history of private enterprise.

Industry in turn is expanding its facilities. Last fall a new General Electric Research Laboratory at Schenectady, New York, was dedicated, which, when completed, will cost $18,000,000. Within sight, and about a mile away, is the Knolls Laboratory of the Atomic Energy Commission, which, by contract, is under the direct management of General Electric Company. The projected cost of this establishment is $37,000,000. Bell Telephone Laboratories have just completed their new installations; Standard Oil Development Company, Standard Oil of Indiana, Goodrich Rubber, Shell Oil, and many others are in the process of building, or have just completed, new laboratories for research.

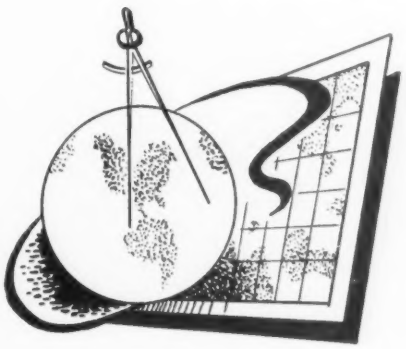
Under arrangements such as that just cited with the General Electric Company, the Atomic Energy Commission is establishing and using numerous laboratories to be operated under contracts with universities and industrial organizations. Carbide and Carbon Chemicals Corporation is operating the Oak Ridge National Laboratory, and the University of California is operating the laboratory at Los Alamos (where work on atomic weapons is centered). A laboratory now under construction near Pittsburgh will be operated by the Westinghouse Electric Corporation. In the outskirts of Chicago thirty-one Midwestern universities and research institutions cooperate in the work of the Argonne National Laboratory; a similar project, the Brookhaven National Laboratory, is located on Long Island. A group of the larger Eastern universities, including Harvard, Yale, Princeton, Columbia, and MIT, formed Associated Universities, Inc., for its administration. In the laboratories built and operated during the war by the Du Pont Company at Hanford, Washington, the Commission is operating, under the management of General Elec-

tric Company, what is probably the largest industrial plant in the United States. This fenced-in and closely guarded area covers 400,000 acres. It is here that we are producing the new element plutonium—the substance of atomic bombs. In April of this year appeared the announcement of a new facility to be built in Idaho for the reactor program.

By this enormous government-sponsored program in the field of nuclear science and technology we aspire in the next decade to an accomplishment such as we have witnessed in this country during the past three decades in the field of chemistry and chemical technology. In the cause of national safety and world peace there seems truly to be no alternative to this procedure. The mere possession by unauthorized groups or individuals of fissionable material—uranium, notably—is forbidden by the Atomic Energy Act of 1946. And aside from this government monopoly granted by an Act of Congress, there is the very practical consideration that the tools used in nuclear research, such as the cyclotron and the nuclear reactors, or "piles," as they are commonly called, are beyond the reach of private enterprise. They simply cost too much.

It seems no longer doubtful that we are definitely trending toward a highly socialized state of affairs in the field of science. One major area is largely controlled by government. A higher percentage of scientifically trained people are now employed on government-controlled and -sponsored programs than can be cited for any other group. The scientific and technical personnel of the overall AEC program are numbered in the thousands. With the enactment of the Science Foundation Bill another step will be taken, although in the beginning it is not anticipated that existing programs will be much extended. The power to spend and plan will, however, be more centralized, and this is the red flag for the opponents of this legislation. They fear the regimentation of science for other than limited national purposes—defense and public health—the control by government of an increasing number of patents, the monopoly by government of research facilities in the universities to the exclusion of industry or of the opportunity for the universities to initiate scientific investigation as in the past.

The atomic energy program is the crucial test. The immediate objective is one of military necessity, but the long-range problem is the development of means for releasing and utilizing the energy of a nuclear reaction. It is still far from certain that this is a technically feasible and economically practical undertaking. Nor is this uncertainty the only risk. It remains to be demonstrated that a government agency is capable of carrying through such an enterprise under the directive of an Act of Congress and subject in the last analysis to the control of Congress. This is in every sense a great experiment. Upon its success or failure depends more than the issue of atomic energy for industrial purposes. We are at work on a new social and economic concept of far-reaching consequence either to a world at war or to a world at peace.



# ALASKA AND THE GEOLOGICAL SURVEY*

JOHN C. REED

*Dr. Reed, who received his Ph.D. from Princeton in 1930, has been with the U. S. Geological Survey since that time. He has made geological surveys in New York, Oregon, Idaho, Arkansas, and Alaska. He is the staff geologist for the Territories and Island possessions in the Office of the Director of the Survey, a governor of the Arctic Institute of North America, and chairman of the Advisory Board of the Arctic Research Laboratory of the Office of Naval Research.*

ALASKA has been American territory for more than eighty years. During that period the resources of this vast area have been developed in a sporadic fashion and in general very incompletely. Nevertheless, in that time Alaska has yielded nearly a billion dollars worth of new wealth in minerals alone. In the Russian days the fur industry was, of course, the big item, and the sea-otter and fur-seal population in Alaskan waters suffered to the point of threatened extinction. The three principal industries of Alaska are now commonly considered to be commercial fishing, mining, and furs, in the order named. To speak of fishing, mining, and furs as the three principal industries may be a little misleading, because such a listing includes only the industries that can be measured in terms of new wealth produced. Other types of activity are very important and should not be omitted; for example, there is the retail liquor industry. In 1947 almost 1.5 million gallons of malt liquors were shipped to Alaska, nearly 400,000 gallons of whisky, and 27,000 gallons of other distilled liquors. Similarly, the construction industry in terms of dollars spent, and including both military and civilian construction, probably outranks any other Alaskan industry at the present time.

At various times in the past impetus has been given to the development and exploitation of Alaska. The initiation and growth of the salmon-packing industry; several gold rushes; widespread mechanization of mining through the introduction of dredges, tractors and bulldozers, draglines, and other heavy equipment; the construction of the Alaska Railroad, which was completed to Fairbanks in 1923; the Matanuska Valley development—all these and many other elements have had their short- or long-lived effect. All of them, however, are minor compared to the changes that began just before America's entrance into World War II and that have continued up to and including the present time.

## FACTORS IN THE DEVELOPMENT OF ALASKA

Today there is a much greater public awareness of the existence of Alaska than ever before. Many men in the military services were stationed in Alaska during the war. They brought back and disseminated much—if perhaps somewhat local and biased—information on the Territory, its geography, climates, resources, and people. A substantial military population is in Alaska now, and it is evident that the military services are greatly interested in Alaska. This interest presumably is the net result of the consideration of many factors. The effect on Alaska is of great importance, and the various military activities are a large, if not the dominant, factor in Alaska's current development.

The international situation inevitably focuses attention on Alaska's strategic geographic position at the northwest corner of North America just across the narrow Bering Straits from the northeast corner of Asia. Noteworthy also is the long finger of the Alaskan Peninsula and the Aleutian Chain stretching to Attu, three quarters of the way from Anchorage to the Kuriles.

The relation of Alaska to global air routes is well known. It has been said that aviation has now reached such a point that no place on the earth is more than three days by air from any other place. A surprising number of great circles between large population centers in the Northern Hemisphere pass through or near Alaska—New York to Tokyo, San Francisco to Shanghai, Minneapolis to Calcutta, London to Honolulu, Moscow to Vancouver, New Orleans to Manila. Already Alaska is served by Northwest Airlines on a regular schedule from Minneapolis to Anchorage and Shemya in Alaska and on to Japan, China, and the Philippines. Northwest Airlines also connects Anchorage directly with Seattle. Similarly,

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Pan American operates from Seattle to Ketchikan, Juneau, and Whitehorse in Yukon Territory, and then to Fairbanks and either Nome or Bethel.

Many airlines operate on an unscheduled basis between the States and Alaska and provide means of transportation for people and for freight of surprising variety. Within the Territory, the airplane is truly Alaska's streetcar. In addition to several companies operating on schedules over many routes between the principal centers, there are many airlines engaged essentially in "bush flying" on wheels, floats, or skis that can land close to almost any point. Many individuals and companies operate their own aircraft either within the Territory or both within Alaska and between Alaska and the States.

Federal expenditures in Alaska, other than military, have been increasing rapidly, especially since the war. Many of the activities are tied closely to military needs, others are not. A good example, though a relatively minor fiscal item, is my own bureau. The U. S. Geological Survey operated in Alaska before the war on an annual appropriation of less than $100,000. In the present fiscal year appropriated funds for Survey work in Alaska total more than $800,000 and with the funds made available from other agencies, including all three military services, aggregate almost $1,125,000.

Civilian construction workers are widely scattered over the Territory and for the most part are receiving exceptionally high returns for their services if returns are considered to include special items of recompense such as food and lodging, special clothing, transportation to and from the States, and high percentage of overtime.

The Alaska highway system is now developing into an integrated net of substantial proportions. The Haines Cutoff connects the coast at Haines in southeastern Alaska with the Alaska Highway in Yukon Territory. The Richardson Highway connects Fairbanks with Valdez. A resident of An-

The Brooks Range traverses Alaska approximately along the 68th degree of latitude or, roughly, 100 miles north of the Arctic Circle. In summer there is little snow on the range because of the scanty precipitation, and glaciers are few and small. (U. S. Navy photograph.)

In good weather, today's air traveler may view the incomparable mountain scenery of the rugged peaks of the Alaska Range. (U. S. Air Force photograph.)

chorage can now drive to Fairbanks by way of the Glenn Highway to Glen Allen and thence over the Richardson, or to the States by using the Tok Cutoff from Gulkana on the Richardson to Tok Junction on the Alaska Highway. Seward is now the terminus of a road leading to Hope or to Kenai on Cook Inlet, and a connection from Anchorage to this road will soon be completed, as well as an extension from Kenai to Homer.

The Alaska Highway is being used to a far greater extent than many of us had anticipated. A complete count at the Alaska border in 1948 showed that 3,227 cars, 824 trucks, and 113 buses entered Alaska over the Highway, and 2,299 cars, 808 trucks, and 133 buses left Alaska. The Highway is open the year round, and, although neither winter nor summer travel over it is to be contemplated too lightly, such travel is proceeding.

## MAJOR PROBLEMS OF THE FUTURE

All the factors that have been discussed are important in the development of Alaska, but many others might be mentioned. Whether Alaska moves forward, or development again slows down as in the past, depends in large part on the degree to which her problems are solved or remain unsolved. Among these problems are the following:

1. *Population.* Alaska needs more people. I am not speaking of military personnel, or temporary construction workers, or seasonal cannery employees, or even those who go to Alaska with the intention of staying a few years to make a stake and then get out. I mean hardy, intelligent, industrious residents who expect to make Alaska their home; the place to settle down, raise their families, and grow with the growth of the Territory. If such people are to become Alaskans in large numbers, they must have opportunities, and to have opportunities there must be industry, agriculture, trade, and adequate living conditions, including housing, schools, and cultural opportunities.

2. *Transportation.* Alaska needs much more adequate transportation facilities and much cheaper transportation rates. The Alaska Highway and other Alaskan roads are not first-class, modern roads; they are not paved. Some are not kept open

throughout the winter. Steamer transportation is inadequate; it is slow, uncertain, and costly. Maritime strikes continually threaten ship transportation to and from Alaska. Only two United States airlines operate on regular schedules between the States and Alaska, and no Alaska line is certified for such service.

Transportation within the Territory by any means—boat, air, highway, or railroad—is still far too limited, too expensive, and too unreliable. More connecting roads would be of especially great benefit.

3. *Housing.* Deficiency of housing seems to be a problem almost everywhere, and in Alaska the shortage is critical. The shortage is most noticeable in the railroad belt at such places as Anchorage and Fairbanks where, in addition to service personnel at near-by bases, there are large numbers of construction workers. Those two cities are also the destination of many of the prospective settlers who have driven to Alaska over the Highway. The deficiency of housing throughout much of Alaska is accentuated by the rigorous winter climate and the extraordinarily high cost of construction materials.

4. *Year-round employment.* A large proportion of the work done in Alaska now is seasonal. Commercial fishing, the largest industry, is a summer activity; so is mining to a large extent, especially placer mining. Even the large construction projects are prosecuted much more vigorously in the spring, summer, and fall, although some construction work does go on throughout the year. Every effort should be made to develop in Alaska industry of the year-round type, or, better yet, industry that could be active principally in the winter in order to use some of the labor that otherwise would be unemployed in winter or would return to the States. To plan or visualize such smoothing of the over-all employment curve throughout the year is very easy on paper but, in a more or less free economy, is very difficult in practice. It is no great feat to plan that a cannery worker in the summer could carve trinkets or make furniture in the winter,

In the central part of the Aleutian Chain are the islands of the Four Mountains, dominated by a group of high, symmetrical cones, among which are Mounts Cleveland and Herbert. (U. S. Air Force photograph.)

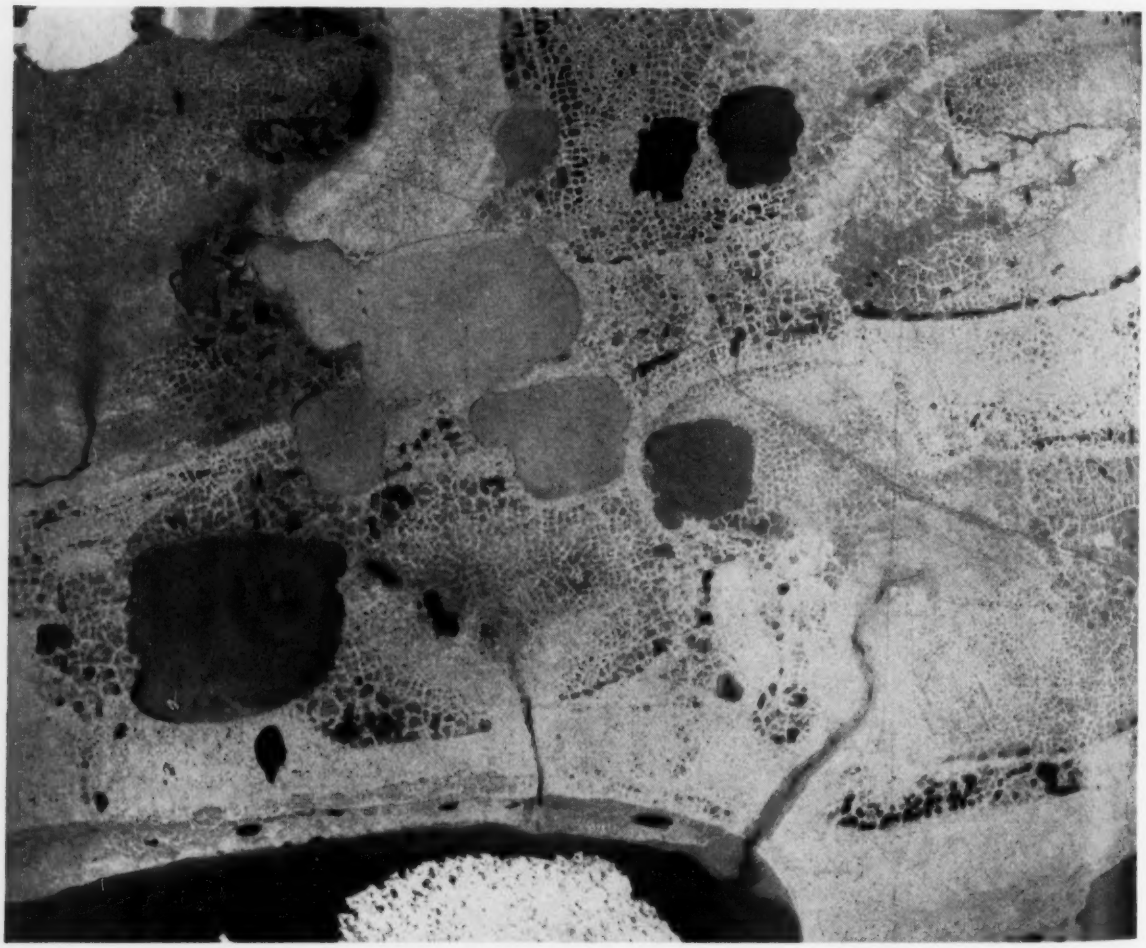
but the cannery worker may have no ability or desire to use his winter in that fashion.

5. *More diversified industry.* Closely related to the problem of year-round employment is that of encouraging and stimulating more diversified Alaskan industry. Many items used in Alaska that must come from the States at present could be found, made, assembled, or grown in the Territory. Any steps toward doing this would provide Alaska with a more stable economy and at the same time would decrease the Territory's dependence on insecure and expensive shipping from the States. Even better would be the establishment and growth of industries that would yield products exportable to the States or elsewhere.

## WORK OF THE GEOLOGICAL SURVEY

Some of the factors leading to the present interest in, and development of, Alaska and some of the problems that Alaska faces have been briefly summarized. Let us now review the responsibilities of the Geological Survey in Alaska to see how they integrate with work now going on in the Territory and with anticipated future development.

The Geological Survey is responsible for the topographic mapping of the United States, for geologic mapping and investigations of mineral resources, for water-resources studies both of surface and underground waters, for classification of the public lands as to their mineral or nonmineral character and as to their water-power potentialities, and for the supervision of mineral leases on the public lands. In short, the Survey is primarily a fact-finding research organization dealing with an important group of natural resources. All the responsibilities of the Survey in the States also belong to it in Alaska.



The complex polygonal surface pattern over much of the Arctic coastal plain of Alaska is a conspicuous permafrost feature. In many places there is striking contrast between present lakes and several generations of earlier ones. (U. S. Navy photograph.)

The Survey is very firmly of the belief that the rational development of underdeveloped areas such as Alaska, and the wise use of the resources with which the Survey deals, depend in large part on a full knowledge of the basic facts. It is the Survey's business to collect, systematize, interpret, and report on certain of those basic facts.

Unfortunately, information on the mineral resources of Alaska, on the configuration of the surface, on its water resources, and on the mineral and water-power classification of its lands is now woefully inadequate. This fact has been generally recognized in this period of interest in Alaska, and consequently the funds and facilities at present available for the Survey's Alaskan activities are far larger than ever before. Large as the program now is, compared with the past, it is still not adequate at the present scale to provide soon enough the fundamental information needed by all the various interests, public and private, that have a part in the Territory's development. Thus the Survey must carefully appraise the various needs and select projects for early accomplishment that appear to be the most important.

In making the field plans for any given year various factors must be considered. Some of the major ones include:

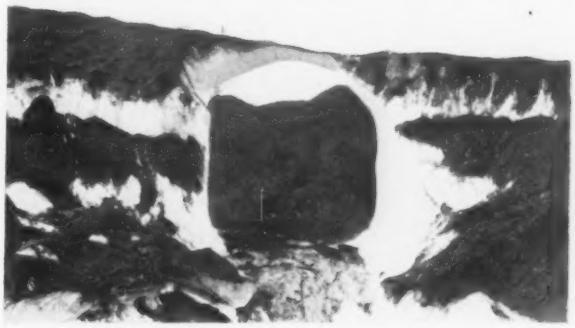
1) Study of the national need for the proposed investigation. Here are considered such things as the position of the nation in regard to, say, a mineral commodity that may be present in the area of the project and the chances of substantially improving the national situation as a result of the proposed project.

2) Appraisal of the Territorial need for the proposed investigation. To what degree may the work contribute to bettering the Territorial economy? Investigation of certain gold-bearing areas, for example, may be of great importance so far as the Territory is concerned but of little or no significance nationally.

3) Consideration of the needs of the military services. Because of Alaska's importance from a defense standpoint, such needs are given a high priority when projects are planned.

4) Balancing of the needs of other Federal agencies. Survey information is a prerequisite to the activities of many other Federal agencies. In general, special consideration is given to projects that contribute to the needs of several other agencies.

5) Fulfilling the requirements of agencies that are making funds available to the Survey for the work. Such requirements must, of course, be given top priority if the funds of others are accepted.



A symmetrical ice bridge formed in the lower part of Muldrow Glacier in Mount McKinley National Park. Size is indicated by figure of geologist (*left center*). (U. S. Geological Survey photograph by the author.)

Thus it is apparent that the matter of programming is quite complex. The planning must be fluid to allow for continually changing requirements and, at the same time, must be designed to permit systematic progress in fulfilling the Survey's general responsibilities, as previously stated.

With the philosophy just outlined as a background, and keeping some of the major problems of Alaska in mind, the Geological Survey is now carrying on the program summarized below.

The over-all program for the summer of 1948 embraced about forty-five field parties widely scattered over the Territory from Ketchikan to Barrow and southwestward to the farthest Aleutian Islands. The work was done in a wide variety of environments and in many different ways. Some parties worked near main settlements such as Fairbanks, others in mining camps; many were in isolated areas, living with facilities taken along. Work was performed with the use of motor vessels, with river boats, some collapsible and transported by air; aircraft were used by most parties, including two helicopters in topographic mapping. Weasels were extensively used in the tundra areas of northern Alaska, and trucks and jeeps elsewhere. The number of parties was somewhat larger in the 1949 field season.

The geologic program now includes work in general, military, and engineering geology, geophysics, the study of permafrost, or permanently frozen ground, and mineral investigations of coal, petroleum, metals, and nonmetals.

Much of the topographic mapping is now done photogrammetrically with aerial photographs in Denver, but ground control must be obtained by surveys in the field. Most of the mapping

work is now on three series of maps—first, a series of general maps of all Alaska on various scales; second, coverage of the whole Territory by a series of topographic maps on a scale of one inch equals about four miles; and, third, a series of topographic maps on a scale of one inch equals approximately one mile. Some of these new maps have already been published, and others will be appearing in increasing numbers.

Although some water-resources investigations have been made in the past in Alaska, they were for the most part sporadic and discontinuous. The present systematic program began about three years ago and is now making substantial progress, although not on a satisfactory scale. Thus far attention has been concentrated in the Alaska railroad belt and in southeastern Alaska. The work now includes both surface-water and ground-water studies, and a quality-of-water laboratory has been established at Palmer, in the Matanuska Valley.

Land classification in Alaska as to mineral, water, and power potentialities is not adequately financed. Nevertheless, some progress is being made toward coal-land classification, and several streams such as Eklutna Creek and the Little Susitna River near Palmer, Ship Creek at Anchorage, and Power Creek near Cordova have been studied for their water and power possibilities.

## ALASKA PUBLIC WORKS PROGRAM

Legislation authorizing the General Services Administration to carry out a five-year $70,000,000 public works program aimed at the intensive development of Alaska and her resources has been passed by Congress and was signed by President Truman on August 24, 1949.

Funds will become available as and when they are appropriated by Congress. It is estimated that the program could involve $10,000,000 in the first year —$2,000,000 in cash and $8,000,000 in contract authority, depending on appropriations, with a proportionate increase in subsequent years.

Sewers, water systems, schools, and hospitals will be provided in the Territory on a matching fund basis. That is, the Federal government, with headquarters in Alaska, probably at Juneau, will build facilities and sell them to individual communities when they have been completed, at prices ranging from 25 to 75 percent of the actual cost. The law provides that the entire public works program will only cost Alaska an average of 50 percent, which really means, of course, that the Territory will receive what amounts to a 50 percent grant in aid. The arrangement whereby the government will build the public works was made because it was felt by the sponsors of the bill, Delegate Bartlett and Governor Gruening, that the costs of administration alone would be prohibitive to most small Alaskan communities.

Incorporated in the law are enabling clauses that permit the communities and the Territorial government to make applications at once, with a minimum of red tape, for whatever facilities may be needed. Because of the over-all 50 percent aid provision, however, it will be necessary that a majority of the applications be in the hands of the General Services Administration before a complete program can be planned.

# AN ANIMAL'S HOME IS ITS CASTLE

DAVID E. DAVIS

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THE old English adage "A man's home is his castle" expresses a desire in man to own and maintain inviolate a suitable place for living. This fundamental urge seems to manifest itself in one way or another throughout the entire animal kingdom. Among vertebrate animals, for example, many fish, reptiles, birds, and mammals confine their breeding activities to a definite area and will defend the spot against intruders. This defense of a restricted area used for breeding is known as territorialism. Each species manifests territorialism in a different manner, showing great variation through the different vertebrate classes.

As a simple instance of the urge to defend a restricted territory, the behavior of the song sparrow may be described from the work of Nice (1937). In the spring, after migrating to the nesting region, each male settles in a well-defined area where he sings and fights to defend the territory, and drives out any male intruders by threatening or by actual combat. When a female arrives, pairing may occur, and the female usually builds within the territory, which the male holds until the young are fledged. During this time the neighboring territories are delimited and defended by other males, and the sparrows recognize their boundaries by mutual agreement. The defense continues until the young are well-grown.

From this briefly described example it may be seen that the behavior of animals in defending a territory presents numerous problems in animal psychology. First, the psychological causes of fighting might be analyzed: one seeks to discover what processes in the nervous system of the individual stimulate him to react to an intruder, what motivations urge him to fight. Second, results accomplished by the defense of a territory may be determined—in some species food is conserved for the young; in others a mate is obtained within the territory. Third, the origin and the course of evolution of these widespread behaviors may be studied.

As in other aspects of animal behavior, it is a difficult task to segregate the various problems under consideration. For example, we see two sunfish, or two lizards, or two robins, or two stags fighting. What are the conditions and causes and motivations of the fighting? Some fighting results in the establishment of an order of dominance or social rank within the group of individuals; other combats are waged in reference to females; still others concern the piece of land owned by an individual. Although there are more functional causes of fighting, we shall here describe only the manifestation of the defense of an area in certain species of vertebrates and mention some questions thereby raised.

The development of the concept of territorialism is relatively recent. Several early ornithologists noticed that certain birds live in a restricted area and maintain a territory. Altum in Germany, Montagu in England, and Bullock in America mentioned the defense of a piece of land. But it remained for Eliot Howard (1920) to propose a comprehensive theory of territorialism based on his intensive studies of the English warblers. His book, *Territorialism in Bird Life*, is considered the greatest stimulus to ornithology since the work of Darwin. It is interesting that Moffat in Ireland in 1903, Mousley in Canada in 1919, and Hammer in South Africa in 1922 independently expressed, although in much briefer form, the same ideas. More recently, many species have been studied in great detail.

## TERRITORIALISM IN FISH

Numerous kinds of fish defend a small area and lay eggs there. The family Centrarchidae, to which many familiar game fish belong, including bass and sunfish—demonstrates this behavior better than any other group. A good example is the common sunfish, *Eupomotis gibbosus*, which breeds in the shallow waters of ponds and small lakes. The male excavates a shallow depression, or nest, with his fins and remains on this nest for much of the day in the breeding season. When another sunfish approaches, he at once attacks it to determine the sex. If the newcomer is a ripe female, she identifies her sex and ripeness by behavior. The male then

induces her to come onto the nest, and fertilizes the eggs as she lays them. If, on the other hand, the intruding fish is a male it raises its gill, thereby displaying the conspicuous scarlet spot that marks its sex. In this case the owner of the nest continues to attack the stranger. In this and many other species the male drives from the nest other males or unripe females even though a ripe female may be absent. The motivation for fighting is therefore presumed to be defense of the nest site, not defense of a female. The function of the fighting is the provision of a place in which eggs can be laid.

### TERRITORIALISM IN AMPHIBIANS AND REPTILES

As yet no account of the behavior of frogs or salamanders clearly describes territorialism for an amphibian. It is known that toads remain in one location for long periods of time and that frogs in the breeding season croak from a particular location. Further studies are necessary to determine to what extent these areas are defended and maintained.

The information concerning reptiles is more adequate. Studies of the lizard *Anolis* (Evans, 1936) show that the males defend a restricted area and maintain a harem. The owner drives away other males but corrals the new females and adds them to his harem. Each female, on the other hand, tends to maintain a small area within the larger territory of the male. One female seems to be dominant over the others, and if not prevented by the male will drive out newcomers. Removal of the testes results in a loss of the fighting instinct, whereas injection of suitable hormones into castrated males or females produces the fighting reaction.

Among other reptiles, available information shows only that individuals remain in an area for a considerable period of time. For example, I observed that a boa constrictor sunned itself daily on a rock beside the laboratory at Barro Colorado Island, in the Canal Zone, and that an alligator lived on a definite section of a riverbank in British Guiana. In these cases, however, the individual may merely have lived in the area without actively defending it. Until more is learned of the behavior of most reptiles, one must speak of the home range of an individual, without attempting to analyze the psychological aspects of its behavior.

### TERRITORIALISM IN BIRDS

The behavior of birds in relation to territory has been extensively studied for two decades. Many species have been investigated, some superficially, a few in great detail. Throughout this group there appears to be great variation in territorial relations. In some instances, it is difficult to be sure that the behavior of the species should be classed as territorial; in others, the behavior, although no doubt territorial, reveals interesting modifications in this respect. The following descriptions of the behavior of several species indicate the extent of the variation in territorialism.

The European reed bunting may be considered a typically territorial bird. In the spring, after migration, the males settle in a definite area, which is defended from other males, if possible, until the females arrive from the south. When a suitable female enters the territory the establishment of a pair occurs. After pairing, the male practically ceases singing, which in this species is primarily a defense measure and an announcement that the male is unmated. During the nesting period there are continuous changes in detail of the territorial boundaries; a newcomer may force his way into an area by obtaining parts of the territories of two or three males. Both sexes defend the boundaries; the females drive out other females, and the males drive out other males. For the second brood a pair may maintain the same territory.

The reed warbler of England, a bird related to North American kinglets, also demonstrates this type of territorialism. The male isolates himself in a part of the reed bed and sings loudly until a mate is found. During the nesting period the male is silent, except for an occasional weak attempt at song, but vigorously defends the territory against intruders. After the young have hatched, the family remains more or less within the territory until the young are able to fend for themselves.

Many species of birds present interesting variations of the territorialism outlined above. For example, the European robin (Lack, 1939) shows a modification that occurs also in mockingbirds and shrikes. The males and the females each obtain a territory in the fall and sing and fight to defend it. In January, however, the females lose the urge to defend the territory and at this time seek males. During the breeding season the females occupy the territories of their mates but do not sing.

The guillemots present a variation that occurs in many other marine species. These birds nest on rocky cliffs, and each pair defends a territory a foot or two in width around the nest site. This piece of land has all the characteristics of a territory but is small in extent. Apparently this restricted type of territory is related to the type of food; since the rocky cliffs used for nesting pro-

vide no food, the birds have no need for an extensive territory. Many other colonial birds, including gulls and terns, occupy a similarly restricted nesting territory.

The phalaropes, an aberrant kind of sandpiper, present a further modification. In these species the female is the more brightly colored sex and courts the male. The male incubates the eggs, and the female usually deserts the nest during incubation, leaving the male to raise the young. As might be expected, the female herself selects and defends the territory.

The European rook, a kind of crow, lives in colonies that consist of many individuals. Each colony maintains a territory and drives strangers away; furthermore, it is claimed that individuals may not leave the group. Within such a colonial territory each pair maintains its own territory around the nest site. This may be a foot or two in width. Since the male defends the territory vigorously, even in the absence of the female, it is believed that he fights for the territory and not for the female. The usefulness of the territory in this case is that it prevents other rooks from stealing nesting material and destroying the nest.

In South America a group of cuckoos, the Crotophginae, has lost the instinct to defend a territory individually. These birds, called anis, live in flocks of five to ten individuals, all of which cooperate to build a single nest. Several females lay in the communal nest, and the whole group defends a territory around this nest site, fighting fiercely to keep out intruders. The birds may pursue an outsider for two or three days to drive it away. They will immediately demolish a dummy bird placed in the territory, and will kill live birds, if they are unable to escape, in a few minutes. Sometimes, however, under conditions not yet understood, the stranger is allowed to join the colony.

Cowbirds present an interesting history of stages in the evolution of territorialism. One South American species of cowbird occupies and remodels a nest of other species of birds and defends a territory around that nest. Another species lays its eggs parasitically in the nest of the first species and apparently defends a territory only during the first part of the nesting period. The North American cowbird lays its eggs in the nest of any kind of bird and probably seldom maintains a definite territory.

The European cuckoo, which is also parasitic on other birds, has slightly different habits. Since each female normally lays its eggs in the nest of only one species of bird, each female maintains her own territory and will not permit another female which parasitizes the same species to enter. But a female cuckoo which parasitizes other species is not driven away, according to present accounts.

The foregoing descriptions indicate some of the variations in the manifestation of territorialism among birds. Many other species have been studied, at least superficially, and fit into the same general outline of behavior.

### TERRITORIALISM IN MAMMALS

Although in birds territorialism is quite well understood, in mammals the situation is not yet clarified. The nests of mammals are primarily places for warmth and sleeping, whereas in birds and other vertebrates the nests are primarily places for rearing the young. This difference may represent a fundamental divergence in the behavior of mammals and birds. Most individual mammals, however, have a definite home range—the area in which the individual lives. Bears and mountain lions cover a large but nevertheless restricted area in hunting. A pack of wolves may range over a hundred square miles in search of food, making a more or less definite circuit from week to week. Apparently each individual limits its activities to a definite home range, and, in general, the males utilize a larger home range than do the females. The provision of food and shelter appears to be the primary function of the home range, and the home ranges may overlap in many cases.

Many rodents live in a very restricted area, each individual occupying a part of an acre. The male of the common white-footed mouse (Burt, 1940) maintains a home range which includes the range of several females. Chipmunks defend a territory which is contained within the home range, and some squirrels defend an area to secure pine cones for food. Fremont's squirrel in Colorado has a churring note used to defend its territory against intruders. At the present time it is difficult to compare closely the home range of a rodent with the territory of a bird or fish. Fighting can be so seldom observed in the nocturnal mammals that there is little basis even for conjecture.

Certain other mammals present behavior that may be considered a true territorialism. Many dogs defend their yards against intrusion by another dog. Male Eskimo dogs, upon reaching sexual maturity, begin to defend a territory by driving away other males. In our domestic dogs, however, territorialism seems to have been masked by civilizing influences.

The red deer of Scotland (closely related to the

American elk) possesses a matriarchial social organization (Darling, 1937). An adult female leads a group of females and young males. The adult males wander about individually except in the rutting season. The herd of deer, led by a female, maintains a territory and drives out other adult females. When the young males reach maturity at the age of two years, they separate from the herd. This organization seems to be territorial in a broad sense of the term.

The behavior of male fur seals during the mating season is clearly territorial. The bull obtains a piece of the rocky shore and drives away all other males. The battles are fierce and frequently result in serious wounds or even death, especially at mating time. One bull may have as many as one hundred cows in his harem, though forty or fifty is more usual. The defense of this area requires much time and energy, and he does not feed for several months during the breeding season, becoming emaciated and battle-scarred. Young males do not fight for a territory until they are about six years of age.

Among the primates, the South American howler monkey, which possesses a patriarchial social organization, is known to maintain a definite territory (Carpenter, 1934). A clan, consisting of an adult male and several females and younger males, maintains a territory partly by vocalization and partly by fighting. The concert of roars produced by two rival males in the defense of the territory can be heard for more than a mile and is one of the wonders of the jungle. Since the territory is large, it is not unusual for one clan to invade for a short time a part of the territory of another group until the owners return.

The gibbon of Siam also maintains a territory for each group, and is of particular interest because it is apparently closely related to the human stock. Each group is locked in its own territory by the surrounding groups. Vocalization, as a substitute for fighting, is used to repel invaders and indicate the territorial boundaries.

## SOME BEHAVIORISTIC PROBLEMS

The foregoing account indicates the widespread extent of occurrence of territorialism. The origin of such behavior is worthy of consideration. For the present one can merely suggest a possible mode of evolution, based on the material now available. In fish, territory is clearly a place for fertilizing and laying eggs, and the necessity for a place for fertilization seems to be the basis of the trait in this group. In some forms the territory is large and in others small, but in all it serves that function. In the lizards, also, the territory secures a location for reproduction. In birds, the behavior has expanded into multifarious types which obscure the origin of the trait. In some primitive birds, however, the territory is clearly a station used in establishing the pair as a social unit. In the black-crowned night heron, pairing and subsequent copulation occur on the nesting platform. The territory extends for a short distance around, above, and below the nest. It seems likely that in other species the territory has been extended around the nest site. It must be remembered that territory has four dimensions and has been extended in time as well as in direction around the nest. This extension in time assumes that a type of behavior has been extended beyond its original use and also develops antecedent to its use. The extension of a behavior pattern forward in time is a common occurrence in birds and probably in other vertebrates. For example, certain species of birds begin to "incubate" before the eggs are laid.

The various types of territory in birds have been classified by Mayr (1935) and revised by Nice (1941). It seems worth while to change the order of the classes in an attempt to suggest a phylogenetic sequence of behavior.

A. Restricted to narrow surroundings of nest.
B. Mating and nesting, but not feeding ground.
C. Mating, nesting, and feeding ground.
D. Mating station only.
E. Winter territories.
F. Roosting territories.

This order supposes that the place of fertilization was the earliest type and that species increased the number of functions served by the territory to include feeding. It must be supposed that the birds in class D have passed through stage B and then discarded the function of territory for nest building. Also, it must be supposed that classes E and F are extensions of the function of territory. The degree of correctness of these suppositions will only be known after more research.

The origin of territorialism has undoubtedly been closely linked with the function or biological value of such behavior in the economy of each species. Territorialism serves different functions in each class of vertebrates and each species. In general, in addition to its pristine function of securing a location for fertilization or copulation, a second important function of territorialism is to provide food for the young. Since the population in an area is trebled or quadrupled during the nesting season, it is essential that adequate food

reserves be present for the young birds. And this food must be obtained with dispatch, so that the young do not become chilled or exposed to predators during the parents' absence. The territory in many species provides suitable food reserves within a short distance of the nest.

Two consequences of territorialism probably occur. The first is an extension of the range of the species, owing to the centrifugal tendency of such behavior. Since each pair of animals forces other individuals to remain at a distance, the species is obliged to spread out over the available nesting habitats. Young birds seeking nesting locations for the first time probably must seek entirely new localities. Thus in many species the individuals are constantly extending the range. The second consequence is the limitation of population. Although data are scanty, at least for some birds the territory can be reduced in size to a limited extent. Hence, a given area can support only a certain number of birds because of the territorial requirements, although colonial territories may overcome this requirement to a certain extent.

When a battle is observed in the field or forest, close observation and careful analysis are required in order to ascertain the motivation. In addition to fighting over territory, other types of combat occur, types easily confused with territorial fighting. Most common is that which has reference to the sex partner (sexual fighting). If a male is seen fighting outside his territory and in the vicinity of a female, it is usually due to the presence of a possible rival male. In the life of fish, sexual fighting is probably more important than territorial fighting. In birds, on the other hand, territorial fighting frequently masks sexual fighting and assumes primary importance.

Another common cause of fighting among members of the same species is the regulation of "peck order," or social dominance. Many vertebrates which live in flocks or schools have a definite order of superiority. A new individual must fight until the proper place is found in the rank of the group. A flock of roosters or of hens, for example, will fight until the social hierachy is established and then, with exceptions due to injury, molting, or age, maintain this ranking by threats which cause an inferior individual to run when approached by its superior. The settlement of the peck order sometimes requires fighting for several days. This type of fighting is not territorial and must be clearly set apart in all descriptions of behavior.

Other types of fighting are interspecific. Some fighting is against predators. The kingbird, which valiantly drives away a hawk ten times his size, is not concerned with territorial boundaries. In fact, both male and female kingbirds will go far outside their territory to attack a predator. Another example of competition between species is the prolonged and fierce fights between starlings and woodpeckers for nesting holes in trees. Such fights may scarcely be considered territorial, because the cavity is the obvious object concerned. However, interspecific fighting may be territorial at times. Even birds make mistakes in recognizing one another. Because of frequent errors of identification, individuals of one species may be mistaken for intruders into the territory of another. Such possible rivals for the possession of the land are driven out as though they were members of the same species. This type of fighting occurs commonly in birds and also in fish.

Each of the aforementioned types of fighting presumably has a different physiological or psychological basis. Certain introductory studies indicate that territorial fighting is based on the endocrine system. In lizards the injection of female sex hormones into males results in a cessation of territorial fighting. In night herons the injection of male sex hormones into females will induce territorial defense. Additional research will undoubtedly indicate the extent of hormonal control of territorial behavior.

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# ANY OLD RAGS TO SELL?

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THE story of rags to riches has no better illustration than in the growth of papermaking. This growth has been made in modern times and has progressed from the small mills where paper was made by hand, in sheets one or two square feet in size, to the present mills that turn out tons of paper each day in rolls eight or ten feet long containing thousands of feet of paper. We now have color in our papers ranging the full breadth of the spectrum and we have papers for almost every conceivable purpose, some of them new and others merely revivals of uses nearly as old as recorded history.

A country such as ours uses tremendous quantities of paper and paper products, with the result that we have come to take paper for granted, little realizing what goes on behind the scenes to make these paper products available to us. It is also difficult to realize that the pulp and paper industry as a whole is classed among the largest in the country; furthermore, as stated by D. Clark Everest (president of the Marathon Corporation), "No other industry . . . has anywhere near the number of scientists, technicians and technically educated people connected with it, directly or indirectly, as the pulp and paper industry."

## GROWTH OF THE PAPER INDUSTRY

Ts'ai Lun is given credit for making the first paper from vegetable fibers about 1,800 years ago. This Chinese experimenter macerated some inner bark of the mulberry tree and some young bamboo shoots, liberating the cellulosic fibers, which he then suspended in water. He dipped out some of this suspension with a screen—probably made of silk fabric—allowed the water to drain off through the cloth, and then set the screen, carrying the layer of matted or felted fibers, out in the sun to dry. He finally stripped off this layer of fibers and had a sheet of paper. Throughout the intervening centuries the basic processes required for making paper have not essentially changed. The first step is that of separating the cellulose fibers from the parent substance, the pulping process; the second is to treat the fibers so that they will felt together into a strong layer, the beating process; the third is to form the fibers into such a layer; and the fourth step is to drive off the water, these last two constituting the papermaking process.[1]

If the printing press had never been invented, and our books, magazines, and newspapers were published with woodcuts or printed with brush and ink, as is done by the Chinese, then such primitive forms of paper might serve our purpose fairly well. The rapid progress in the graphic arts not only gave papermaking its greatest impetus, but, in modern times, has placed demands upon our papers that were not dreamed of by the printers of the Gutenberg Bible. Higher-speed printing presses require paper of greater strength and ink receptivity, and multicolor offset printing demands paper that does not change dimensions or curl with changing moisture content. Fine illustrations must be printed on paper with a clear, smooth surface. These are but a few of the difficulties confronting the printer who uses new and constantly improving printing processes. The properties of the paper he uses can send him home in the evening muttering in his beard, a menace to his family, or in a mood to take them all to the movies.

For most of its history papermaking was an art (a heathen art at that) which, after it had been introduced into Europe by the Moors, was practiced exclusively by heretical groups. Only in recent years have science and technology been applied to this art. Through this application great strides have been made, not only in the quality and quantity of paper produced, but also in the growth of new and allied industries. Even in the past twenty years there has been phenomenal growth in the size of the industry and in the numbers of technical personnel involved. In 1928 the annual consumption of paper and paperboard products was 12.5 million tons; by 1948 it was 26 million tons, which were furnished to the country by approximately 800 mills.[2] In 1928 there were about 233,000 wage earners in the pulp, paper, and allied products industries earning $287,000,000

in 1948 there were 394,000 workers drawing $1,063,000,000 in wages.[3] Of these, 3,557 were specialists who are members of the Technical Association of the Pulp and Paper Industry. This figure does not include technical personnel not belonging to that organization.

### RAW MATERIAL SHORTAGES

Few modern industries possess the heritage that has been handed down to the manufacturer of paper. Throughout its whole history papermaking has been subjected to economic pressures, and in turn it has forced new inventions and the creation of new industries. The first such pressure felt by the papermakers was that caused by shortages of the raw materials from which fibers could be obtained. The first source of fibers was wood, that is, bamboo wood and mulberry bark. By the time the Christian world acquired the art of papermaking (about A.D. 1100) the source of fibers was old linen rags. The tremendously enlarged market for paper that was created by the invention of the printing press brought about an acute shortage of rags; this situation led the more venturesome craftsmen to experiment with cellulosic fibers from grasses, straws, and other plants. This experimenting still goes on. The chemurgic program and the government regional laboratories are constantly seeking new fiber sources that can be used for paper and paper products.

To return to the rag shortage problem, it is interesting to realize that the first government "directive" was an order from our Continental Congress demanding that old rags be saved and collected for use in the infant paper industry. In this colonial period,

> Scarcity of paper gave printers more trouble than any other factor. A papermill, built shortly after 1690 on Paper-Mill Run, a tiny stream in Germantown, started the industry, but even the English mills produced less than £25,000 worth of paper in 1690. The absence of sufficient rags, paper's chief raw material, long rendered domestic manufacture precarious and importations costly. The financial insufficiency of the colonists and persistent British opposition contributed heavily to the lag of paper making behind paper using.[4]

### THE DEVELOPMENT OF WOOD PULPING

The keen observation of Reaumur, a French naturalist, that wasps' nests were made up of layers of a paperlike material and that bees got their raw material from old wood evolved, eventually, into our modern pulping industry. Pulping processes are designed to obtain cellulose fibers suitable for the manufacture of paper and paper products. For some types of paper products, destroying the original structure of the wood or other parent material is sufficient, but for higher-quality pulps the pulping process must also free the cellulose fibers from lignin, resins, pectic material, and other noncellulosic constituents.

Papermaking in Europe in the seventeenth century.

With the return to the use of wood fibers and the advent of the modern wood-pulping processes, the shortage of raw material appeared to be a thing of the past. That nothing is static or permanent with respect to science and technology is illustrated by the fact that, with apparently unlimited sources of pulp, new industries were created that used this new supply to manufacture new paper products. In 1918 our per capita consumption of paper (all grades) was 121.2 pounds, in 1928 it had increased to 207.8 pounds, and in 1948 it was 358.5 pounds. We are far from self-sufficient in the matter of wood pulp, for this huge consumption of paper products necessitates the importation of more than 2 million tons of pulp from Canada, Mexico, Newfoundland, and Europe. In 1948 we produced 12,872,000 tons of pulp in our own country.

The multitude of paper and pulp articles that our children take for granted and that we deem essential to our everyday life were nonexistent

only a few years ago. For example, about the only paper containers we had in those "good old days" were brown paper sacks and shoe boxes. (What would lunch on the train have been without them?) Now, thanks to research, those brown sacks are white, and the architects of shoe boxes have put "picture windows" in them, and they are being used for everything from their original purpose to the marketing of frozen foods. The exigencies of World War II promoted the application of technology to such things as paper containers that could be unloaded from boats by dumping them into the ocean and letting them float ashore, and to the more difficult production of containers that would prevent the passage of moisture vapor which, in turn, would spoil the contents. The suggestion is made that the per capita consumption of paper and paper products can be used as a barometer to indicate the standard of living of a nation.

### THE NECESSITY FOR A CONSERVATION PROGRAM

These greatly expanded uses for wood pulp have put a tremendous strain upon our resources of wood, for it requires approximately 2 cords (128 cubic feet) of wood to make one ton of chemical pulp by any of the standard processes. The free and easy days of the old-time sawmill, with its small investment, and the prodigal use of our timber resources are over. There is too large an investment today in permanent buildings and expensive machinery for the pulp mills to abandon cutover forest land and then move on to virgin stands of timber. We are now forced to grow trees as a crop and replace them as we use them. A Forestry Service report of February 21, 1949, points out, with respect to good forestry management, that the best showing is by the lumber and pulp companies, which together own 15 percent of the commercial forest land in private ownership. Small holdings, which comprise three fourths of private forest land, are said to be "the toughest problem."

> Land owners can now be told, truthfully, that growing and harvesting crops of trees is a profitable business. Many small owners, who once believed that timber land burned over and used for grazing was more valuable than when used as a fully stocked wood producing area, have changed their minds. They now see prospects of more substantial and adequate returns in production of pulp, poles and timber, than in the growing of hogs, sheep and cattle. The profit motive is giving point and purpose to mass education in forest practices.[5]

Of increasing importance is the integrated lumber and pulp mill which utilizes waste material from the sawmill for the manufacture of paper and rayon pulp. This has been made possible by better methods of utilizing the trees, by better methods of bark removal from logs and larger branches, and by good management of the lumber companies. More of such intelligent use of our resources is necessary; otherwise we shall be facing even more critical shortages. Our predictable increase in population in the next ten years alone could cause this.

Conservation as advocated by the Forestry Service and many of the states presents some of the most difficult problems for technology to solve. Many pulp and paper research laboratories are engaged in finding ways of profitably using the lignin that constitutes 20–30 percent of the wood. Synthetic vanilla flavoring and molding resins are two of the more spectacular products that have been developed to commercial use. The research work on lignin and other waste materials from the pulping industry has been intensified by legislation directed toward cleaning up our rivers. The sulfite-pulping process is the worst offender in stream pollution, for, unlike the alkaline-pulping processes, since the chemicals in the cooking liquor cannot be recovered, they have been dumped into the streams. Much expensive research has been devoted to this problem, and at least one possible answer has been obtained. This consists, very briefly, of using either the magnesium or the ammonium bisulfite rather than the calcium compound as the cooking chemical; either chemical can be recovered for reuse. The lignin and other products separated from the cellulose fibers still present a disposal problem. At present they are burned for the production of power. This is but one of the many stream-pollution problems to be solved and constitutes too large a research program for any one mill to undertake. The industry has banded together in the National Council for Stream Improvement (of the Pulp, Paper and Paper Board Industries), Inc., to finance comprehensive work at such research laboratories as the Institute of Paper Chemistry, Mellon Institute, Kalamazoo College, Louisiana State University, Purdue University, Virginia Polytechnic Institute, Bates College, Rutgers University, Manhattan College, Oregon State College, and the University of Washington.

### SAUCE FOR THE GOOSE IS NOT SAUCE FOR THE GANDER

To return for a moment to the original economic pressure of rag shortages, what about our supply of rags for paper at the present time? This question is still critical to the mills that make rag-

content papers. The reason, however, has changed. The new cotton fabrics developed by textile technologists contain synthetic threads which ruin the rags for papermaking. Thus progress in the field of textiles is forcing the rag-content paper manufacturers to seek new sources for cotton fibers. They are doing the obvious—that is, going back to the original cotton plant for their papermaking fibers. The instability of the cotton market has been a constant deterrent to such a change from rags to raw cotton. This same uncertainty directed the rayon manufacturers to change from cotton to wood pulp, a move which some fine paper manufacturers made when highly purified wood fibers became available. The pulp manufacturers, through their newly refined pulping processes and bleaching operations, have rendered it possible for the papermaker to produce finer grades of paper from these wood fibers than any that were attainable a quarter of a century ago.

## MAKING PAPER

*The beating process.* An essential operation in papermaking is that of treating the fibers so that they will felt together to form a strong sheet. This is a mechanical process of rupturing or fraying out the outer layers of the cellulose fiber so that tendril-like fibrils project from the parent fiber. Many theories have been propounded to explain the process and its effect upon the felting properties of the fibers, but it will suffice to bring out here that the degree of such treatment, or "beating," governs the manner in which the fibers mat together to form a sheet of paper. This operation is critical because the rate at which the water drains from the fibers on the wire (or screen) of the paper machine determines not only the production rate but many of the properties of the final sheet. Means of testing and predicting this behavior are still a controversial subject among paper technologists.

The first "beating" was probably done with a rock or sticks of wood, later on with a big mortar and pestle. Stamp mills were used by the early European paper mills, but the slowness or small production rate and the high power consumption of such devices inevitably led to a more efficient machine. Such a machine was invented by a Dutchman (whose name has been lost to posterity) and

Washing and beating of pulp in Hollander-type beaters.

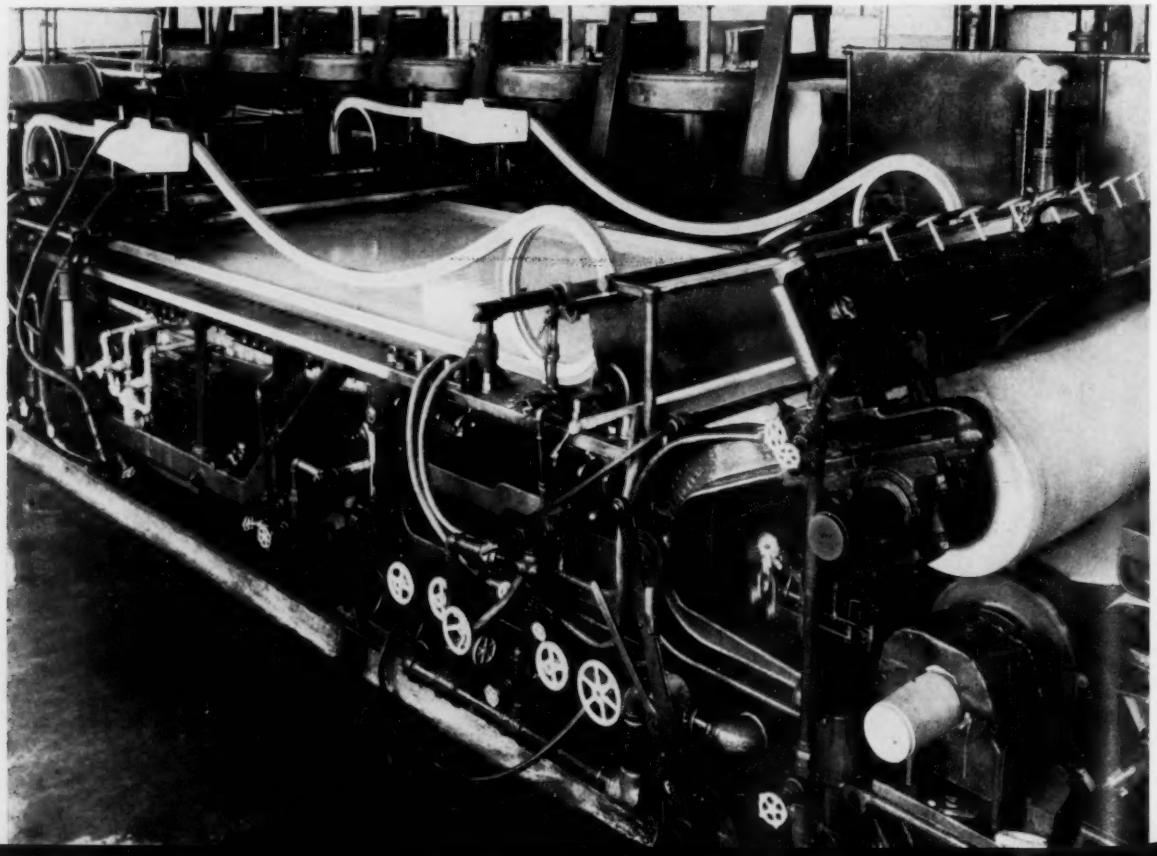
was called the "Hollander." With slight modifications, this type of machine has been in general use for nearly 250 years. Within the past few months experimental information has been released claiming that a new machine puts a "permanent wave" into the fibers and thus increases the desirable felting and strength properties demanded of paper, but without the excessive fibrilation and cutting of the original fibers done by the "Hollander" beater.

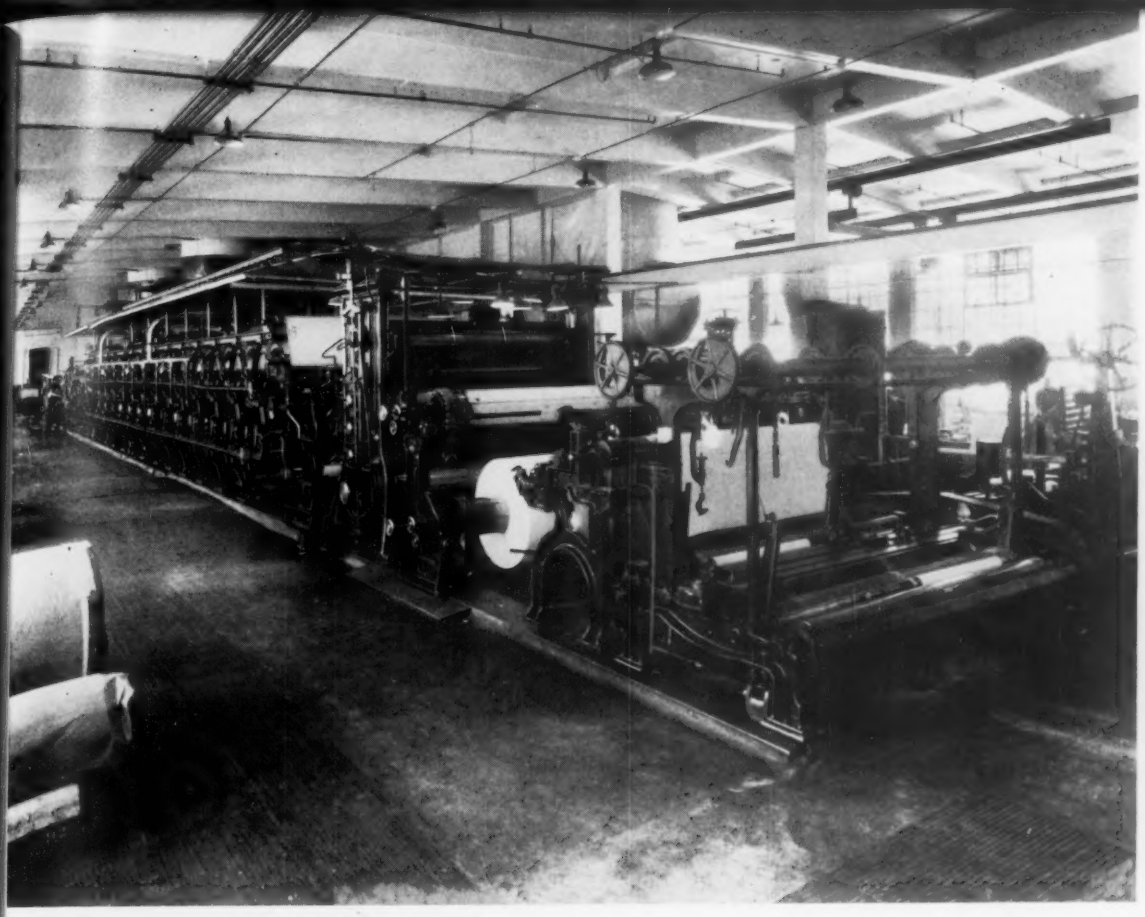
*The paper machine.* Much energy has been expended by engineers in the design and construction of paper machines that will make paper at a greatly increased rate, assure an even flow of pulp suspension onto the endless belt of wire screen on which the fibers are felted into a sheet, and effect other minor refinements that improve both production rates and quality. The essential features of the machine invented by Louis Robert and developed by the Fourdrinier brothers still remain. These are, in the last analysis, nothing more than applying the fundamental method of Ts'ai Lun to a continuous operation that makes a sheet of paper of indefinite length rather than individual small sheets.

*"Sizing" of paper.* The ancient Chinese currency, ceremonial, writing, and wall papers required a treatment that prevented the spreading and penetration of their inks and paints. This was accomplished by dipping the sheets of paper into water dispersions of rice flour or starch. The early European papermakers used animal glue for this purpose. In modern parlance this is called "tub sizing," and the two chief raw materials have been starch and glue. Scientists, however, have been responsible for "modified" starches, as well as for improved techniques in the use of both starch products and animal glue. They have also developed new cellulose and starch derivatives that are being tested in paper-mill laboratories with the ever-present hope that better papers at lower cost or papers for special uses can be obtained.

In 1800 Illig contrived a new way of sizing paper. His method consisted of stirring a rosin soap in with the water suspension of fibers in the beater and precipitating the rosin on the fibers with an acid or an acid-producing material such as aluminum sulfate. For many requirements no subsequent tub sizing was needed, but, for papers highly resistant to water or writing inks, both types of sizing were necessary. Probably the chief objection to this rosin-sizing method has been that it was not always dependable. Furthermore, it is probably no exaggeration so say that every re-

"Wet end" of paper machine showing the formation of the sheet on the "wire," or endless belt of wire screen.





"Dry end" of paper machine showing steam-heated drier rolls, calendar stack, and rewinder.

searcher in paper technology has tried to find a better material than rosin for this purpose. Other materials have been found, but the economic competition based upon cost has always been in favor of the cheap and easily handled rosin sizing. Combinations of rosin with other materials, such as waxes, have been developed, but they have not received general acceptance in the industry—except that they are quite useful for special papers. Recently a more successful attack has been made on the rosin-size problem; this is based upon increasing the efficiency of the rosin as a water repellent. Fundamentally, this operation depends upon keeping the precipitated rosin particles in sufficiently fine state of subdivision so that a given quantity will have greater "covering power" in the sheet of paper. Animal glue, casein, soybean protein, cellulose, and starch derivatives have been employed for this purpose with varying degrees of success, and some of them have been developed into patented processes.

The voluminous literature on the subject indicates that the basic theory of the mechanism of rosin sizing has been, and still is, a controversial one. New techniques developed by microscopists have settled the question as to whether the rosin is deposited on the fibers as a layer or as microscopically small particles looking like nodules. The latter having been established as correct, the colloid chemists have been called upon to explain how such a deposit can prevent the flow of inks and other water-dispersed systems around these particles and thus through the paper. The answer has been based upon the phenomenon of "adhesion tension," which is indirectly measured by the angle of contact of the fluid on the solid paper surface. Having been introduced to papermaking, the colloid chemists have had a field day studying many other phases of paper technology. They have found, for example, that variations in the *p*H of the glue tub size have a pronounced effect upon the manner in which it sizes paper effectively. They suspect that the differences in the magnitude of the electrical charges on the cellulose fibers and the surrounding water system in which the fibers are suspended govern the surface activity and therefore the manner in which the fibers felt together. (Work of this nature has recently been started at the Pulp and Paper Research Institute of Canada.) Such underlying research obviously included studies of the structure of cellulose from different sources. Microscopists are making valuable con-

tributions to this knowledge through the use of light microscopes, the newly developed phase contrast techniques, and the electron microscope.

*Bleaching.* Bleaching is generally accomplished by the use of chlorine or compounds of chlorine. This treatment makes the pulp appear brighter by reflected light by rendering coloring matter soluble (either by chlorination or by oxidation) so that it may be readily washed out from the pulp or rag stock. This result suggests that the operation involves two problems: regulating the action of the bleaching agent on the coloring matter so as to obtain a maximum quantity in a soluble condition without at the same time chemically damaging the cellulose; and washing out the solubilized coloring matter as completely as possible. The introduction of multistage bleaching afforded a means of carefully controlling the reaction on the coloring matter and also a means of washing this material from the fibers at intervals to accomplish its more complete removal. The number of such stages may vary from two to six. The time-honored bleaching agent has been chloride of lime, but in recent years chlorine gas, sodium hypochlorite, chlorites, and hydrogen peroxide have been successfully applied to commercial operations. The success of these newer methods has been due, in no small measure, to better engineering design of bleaching equipment. These improvements in bleaching have made possible the more extended use of such wood fibers as sulfate or Kraft pulp, and this practice in turn decreases our dependence upon a few selected woods, such as spruce and hemlock, for white pulps.

*Fillers.* The brightness of a paper is obtained not only by the bleaching of the pulp and rag fibers but also by the proper use of fillers and dyes. Fillers have other functions as well. China clay, for example, has long been used as a "loading" material to increase the weight of paper and give it greater opacity. In the fine paper field, brightness and opacity are the properties sought from a filler. If cellulose fibers can be packed so closely together in a paper that there are practically no air spaces between them, a transparent sheet is obtained which is termed "glassine." On the other hand, if the fibers are loosely packed, we get an opaque and bulky paper such as blotting paper. If, however, opacity is to be gained without bulkiness, a material must be incorporated into the paper that has an index of refraction sufficiently different from that of cellulose so that light transmitted through the sheet is scattered. The commercial development that produced titanium dioxide pigments furnished the papermaker with one of his most efficient fillers. Although expensive, its very high refractive index reduces the amount required to obtain the necessary opacity for book and bond papers.

*Coated papers.* Mention has been made of the smoothness of paper demanded by some of the modern printing processes. This brings us into the field of coated papers, a large and specialized subject in itself. Unlike the tub-sizing process, coating of paper leaves a definite layer of the coating upon the surface. Without going into the technology of this branch of paper manufacturing, it can be pointed out that the old casein-china clay mixes are being supplanted by newly developed proteins, starch, and cellulose derivatives, as well as lacquers, which, combined with new pigments, give greater latitude to the printer in the choice of coated papers. Packaging experts are also finding greater choice in coated papers that are both more decorative and more serviceable.

*Technical papers.* Probably the most stringent requirements that are placed upon any papers are those of the "technical" papers. This broad classification includes artist papers, tracing papers, and those on which light-sensitive coatings are applied. Art papers require permanence of color and certain intangible properties of "texture." One cause of yellowing of paper is the oxidation of the rosin sizing that slowly takes place during aging of the paper. In comparatively recent years, the producers of rosins have offered a hydrogenated rosin which does not undergo this color-producing reaction and which, for this reason, is recommended for "permanent" paper. Some of the requirements for blueprint paper are that it possess high wet tensile strength and sizing adequate to prevent penetration of the coating solution through the paper. On the other hand, it must not be so water-resistant that it inhibits the absorption of a sufficient and uniform amount of this solution on the surface. Wartime research developed urea-formaldehyde and melamine resins that impart exceptional wet strength to paper, but some of these cannot be used for photosensitive papers because other properties will suffer harmful effects, such as the "spoiling" or predevelopment of blue color in blueprint paper. Some of the newer resins appear to have overcome this difficulty.

Twenty years ago nearly all technical grades were 100 percent rag papers. The depression of the 1930s forced the papermakers to learn how to produce less expensive but equally satisfactory technical papers from wood pulp and rag mixtures.

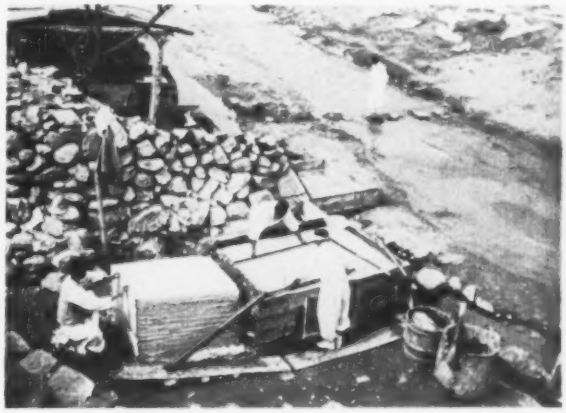
The resultant mixtures of different types of wood pulp and rags, with their many and varying properties with respect to formation on the wire of the machine, and their sizing characteristics, are still problems of the papermaking industry.

These are an illustration of but a few of the difficulties that have confronted the technologists working on technical papers, and, although the final answers may not have been found, considerable improvement in these papers has been made. Then, too, one might ask, What *is* a final answer in scientific research, with its ever-changing horizons?

## NEW ALLIED INDUSTRIES

The specialty paper field is replete with new products that have been the result of recent technical developments by the paper technologists. A compiled list of these articles would be long and tiresome reading. A rapid scanning of the index to *The Paper Year Book* shows 53 kinds of bags and sacks, 9 kinds of blotting paper, 13 kinds of book paper, 33 of boxes and cartons, 21 kinds of envelopes, 34 kinds of paper board and 21 kinds of wrapping paper. The 21 kinds of envelopes, for example, mean not sizes but different use requirements. A more interesting way of gaining a realization of these newly developed products would be for the reader to go on a shopping tour and make note of the things he could not have bought as a youngster. A surprizingly large number of these would be found to be made of paper or pulp. Some of them might not be easily recognized, for they appear to be made of "plastics" and molding resins. To give added strength and other desirable properties to many of the molded resin products, highly purified pulps or cellulose fibers are used as "fillers" in the resins.

Many of us can remember watching the construction of a new house and the particular fascination of seeing the lather, his mouth full of nails and a specially designed hatchet in his hand, put up lath with extreme speed and dexterity. No highly skilled labor is needed for that part of construction these days, as large sheets of wallboard are put in place very quickly. Some types of wallboard are sheets of plaster covered on both sides with paper. Other types are made either from by-products or from refuse materials. Bagasse from cane-sugar refining, straw and cornstalks from the farm, and wood pulps that will not make better grades of paper have furnished the raw materials for some of the more recently developed wallboards.



Korean workers using ancient style hand-sheet mold.

Thus it can be seen that the art of Ts'ai Lun, carried on through many centuries with little or no essential change, has, in comparatively recent years, been subjected to economic pressures that have changed papermaking from an art to a technology, forced the growth of the industry to gigantic size, and increased our dependence upon paper and paper products. In some cases these products are poor substitutes for the objects they attempt to supplant on the market, their chief sales appeal being either their novelty or their cheapness. On the other hand, many of them are not merely substitutes but fill very definite needs in our daily lives. In either case the pressures in our free economy present many challenges to paper and allied technologists.

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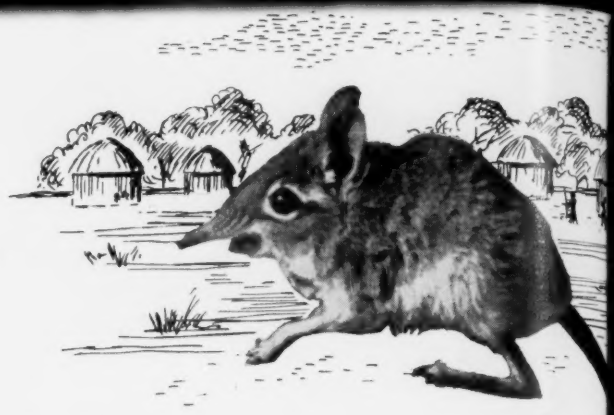


# AFRICA FROM NUBIA TO TURKANA

WENDELL PHILLIPS

*The University of California African Expedition was organized by Mr. Phillips in the fall of 1947 and spent most of the ensuing year in Africa under his leadership. With the aid of more than fifty scientists and technicians, investigations were carried on in twenty-two countries, from Port Said to Capetown.*

UPON the completion of the varied programs of the University of California African Expedition in Egypt and Sinai (see "Recent Discoveries in the Egyptian Faiyum and Sinai," *Science*, 1948, **107**, (2791), 666–70), the major section of the Northern Party, under Expedition Field Executive William B. Terry, traveled up the Nile, crossed the Libyan Desert, and began work at Wadi Halfa in the Sudan.*

The United States Naval Medical Science Group, whose participation had been arranged through the Bureau of Medicine and Surgery (Rear Admiral Lamont Pugh, MC, USN, Deputy Surgeon General) and the Geophysics Division of the Office of Naval Research, in collaboration with the Regents of the University of California, had the following major objectives in Africa:

1) To obtain an intimate knowledge of certain tropical diseases, their diagnoses, clinical manifestations, treatment, and methods of control and prevention.

2) To utilize this information for the prevention, treatment, and control of tropical diseases in the Armed Forces, wherever these diseases might be encountered.

3) To make colored motion pictures and clinical photographs to serve as material for teaching purposes at the United States Naval Medical School, Department of Tropical Medicine.

4) To collect insects, animal hosts of disease, and clinical specimens for teaching purposes.

5) To conduct research in parasites of birds, mammals, and reptiles, with emphasis on parasites related to human diseases.

6) To collect scientific specimens for research workers in civilian institutions, to help fill in important gaps in their scientific collections.

## SUDAN

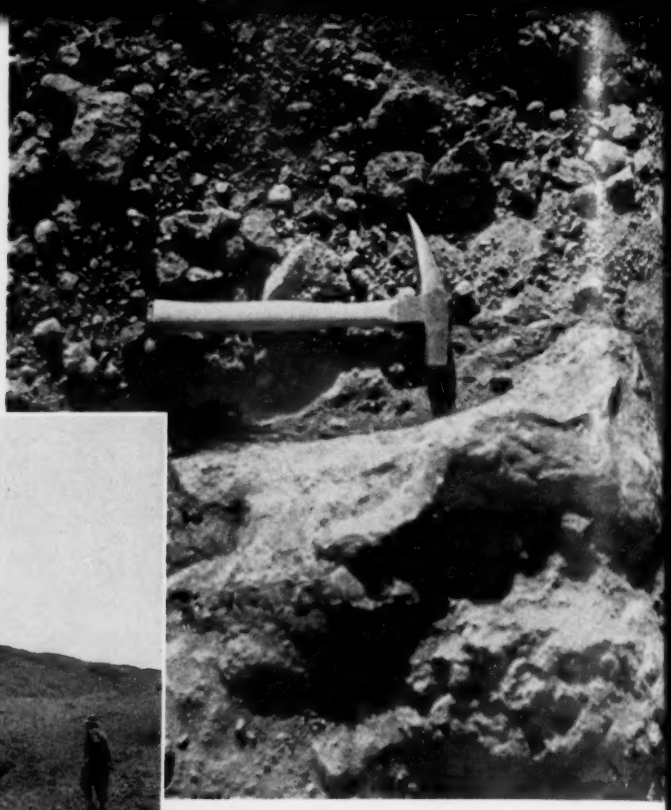
*Tropical medicine.* The first shakedown of laboratory equipment to be used in the field throughout Africa was made at Wadi Halfa prior to entering the Nubian Desert; parasitological and X-ray equipment, particularly, were given their first workout. Hunting parties began their nightly trips into the desert, discovering that game such as jackal, hyena, desert fox, and hare ranged far and wide, and came close to or even into town. The specimens were photographed and combed for ectoparasites, of which they carried considerable numbers. These were carefully put into preservatives for taxonomic study and correlation with human disease if possible. The animals were then examined for intestinal and other internal parasites, and all these were preserved for further study in America.

Ward rounds were made at the local native hospital with the Sudanese district medical officer, Dr. Mohammed Ahmed Ali. Many types of fractures were seen at Wadi Halfa, as well as many contagious diseases and other interesting medical phenomena. X-ray pictures were taken for the benefit of the patient and to aid Dr. Ali in the diagnosis and confirmation of his findings.

At Wadi Halfa a species of chironomid fly, which came up out of the Nile about sundown, was

* The staff of the Expedition's Sudan phase included Gladys Terry, business manager; Dr. Henry Field, physical anthropologist; Commander Julius M. Amberson, MCR, USNR, medical officer (in charge of the Navy Medical Program from Cairo to Nairobi; Captain James J. Sapero, MC, USN, directed the Medical Program from Nairobi to Capetown); Commander Trenton K. Ruebush, MSC, USN, parasitologist; Harry Hoogstraal, mammalogist-entomologist; Dr. Ernest Schwarz, zoologist; Chief Hospitalman Deaner K. Lawless, USN, medical research assistant; Photographer's Mate 2/c Harley F. Cope, USN, naval photographer; M/Sgt. Charles D. Evans, USMCR, motion-picture photographer (in charge of motor transport in the Sudan after the return to America of Transportation Chief Major G. G. Edwards, USMC, who was injured while serving the Expedition); Keith Marker, motor transport; Richard Alison, assistant mammalogist; and Walter Thompson, technical assistant.

Warriors of the Masai meet to hear an address by the British Governor of Kenya.



Rhinoceros skull in rock, Turkana.

Fossil beds, Kenya Colony.

Mesolithic skeleton, showing artifacts, Turkana.

Skeleton in Neolithic burial mound, Turkana.

Expedition vehicles crossing the Sobat River.

present in enormous numbers. The medical authorities at Khartoum have shown them to be the cause of an asthmatic condition, and to some of the acute asthmatics benadryl was administered with good effect. Diabetes was seen among the Sudanese population both at Wadi Halfa and at Abu Hamed. The direct cause for this is not known, but the fact that the diet of these people is largely carbohydrate, with low amounts of fats and proteins, may be an explanation.

At Abu Hamed, on the great bend of the Nile, no doctor was available, but a trained African medical assistant administered to about 10,000 people in this general area. In this latitude there were a few cases of yaws and some malaria, but other than this the diseases were those that are also problems of the European. The black fly *Simulium damnosum* occurs in abundance in this region. This fly is a known carrier of onchocerciasis, a disease caused by a worm that lives in human tissues. In certain areas the worm produces epidemic blindness.

After breaking camp at Abu Hamed, the party crossed the Atbara River, which is the last tributary that feeds the Nile in its northward flow to the Mediterranean; it forms an important barrier between the Mediterranean fauna and the true African fauna. According to Dr. Schwarz, although there is no absolutely sharp line of demarcation, it can be said that the desert fauna, of which the Mediterranean red fox (*Vulpes vulpes aegyptiaca*), the common gerbil (*Gerbillus gerbillus gerbillus*), and the dorcas gazelle (*Gazella dorcas littoralis*) can be taken as index species, fades out from the Atbara River line, and disappears from the Blue Nile at Khartoum, and that the true Sudan fauna, with baboons and many species of true antelopes, appears south of the Atbara. Another important line is the Sobat River, in the valley of which there is a secondary overlap of the ungulates of the Sudan and the Uganda fauna. This is due to the disappearance of the forest screen which connected the Uganda forest with the relict forest of the Imatong and Didinga mountains. That this screen has disappeared fairly recently is shown by the identity of the fauna in these mountains with that of the primeval equatorial forests, as demonstrated by the occurrence in both areas of the blue monkey (*Cercopithecus mitis stuhlmanni*), and the blue duiker (*Philanthomban monticola aequatorialis*). From the equatorial forest the shifts of fauna obviously have an influence on the spread of infections and parasites of which the animals are reservoir hosts. A vegetational change occurs at this point, the plants being greener and of more variety on the south bank.

At Khartoum extensive studies of the medical problems of the entire Sudan were conducted. There were visits to the Kitchener School of Medicine, Graphic Museum, Zoological Gardens, Cotton Research Station at Shambat, and the Veterinary Research Station, and discussions with various missionaries who were in Khartoum or passing through on their way to other outposts. Here, also, the first definite information on the location of the elephant shrew was obtained. Donald McClure, a Presbyterian missionary in the Sudan-Abyssinian border country, told us that the animal might be found near Kapoeta, Equatoria, in the southeastern Sudan. In this area Dr. Schwarz studied the distribution of the commensal rats and mice and showed that the Norway rat does not occur anywhere in the Sudan along the Nile itself. The material examined at Khartoum showed that previously published records were incorrect and that the animals identified as Norway rats were white-bellied rats (*Rattus rattus frugivorous*), which belong to the black rat group. The discovery of the white-bellied Mediterranean house mouse (*Mus musculus praetextus*) in Khartoum is the

Tribes of the south-central Sudan include (*left*) Dinkas, and (*right*), Nuers, who wear no clothing.

southernmost record of it in the Sudan so far. It was learned from the Sudan medical people that hydatid disease, or *Echinococcus granulosus,* might be encountered in the same region.

At Wad Medani the first real tropical diseases were found. Cases of madura foot, kala azar, tropical ulcers of the extremities, malaria, schistosomiasis, anemias, and parasitism were observed and photographed. Visits were made to the Agricultural Research Station, where extensive studies in cotton and other economic crops of the Sudan are in progress. The snail hosts of schistosomiasis are also under intensive study here.

Typical clinical manifestation of tropical ulcer.

After leaving Wad Medani, we crossed Gezira Triangle and set up camp near Kosti, where tropical malaria was prevalent. Here nets were used for the first time, and all members of the party began to take suppressive doses of atabrine or paludrine. A trip was made across the river to visit the Kosti Native Civil Hospital, where cases of madura foot were present in greater numbers and variety than heretofore. Following a road and trail along the White Nile, en route to Juba, stops were made at Malakal, Er Renk, Paloich, Bor, and Mongalla, which was once the provincial capital but is now in ruins, having been abandoned because of the prevalence of malaria and blackwater fever. The capital has been moved to Juba, which is on higher ground and less infested with mosquitoes. At Bor an epidemic of smallpox was encountered among the natives.

Headquarters for the next six weeks were established at Juba, and from there parties were sent into both the eastern and western portions of Equatoria. At Juba it was found that elephantiasis in the native was due to *Onchocerca volvulus.* This is not a new discovery, but it has been thought that in most places the disease was due to *Wuchereria bancrofti.*

In eastern Equatoria province, Commander Julius M. Amberson, MCR, USNR, assisted a Sudanese doctor with numerous laparotomies on natives ill with *Echinococcus granulosus.* Cysts were obtained in the course of these operations and preserved for the U. S. Naval Medical School. Considerable effort and attention were given to a survey of the blood parasites of the indigenous fauna. At Kapoeta the most interesting find was that of a peculiar malaria in the blood of the elephant shrew. This parasite, it was hoped, would be of some value as a laboratory research subject, and field studies on the parasite and its hosts, in addition to acclimatization studies of the hosts, were made. One hundred and four living elephant shrews were then returned by air to the Naval Medical Research Institute at Bethesda, Maryland. There it proved that the species of malaria had such a peculiar cyclic course that it would have little value for comparison with human malaria; it will, however, shed light on the taxonomic and evolutionary status of the malaria parasites of man and animals, and as such could be very useful.

After the shrews were returned to America an attempt was made to discover the vector of the parasite in the Sudan, but with only makeshift facilities available the problem proved insoluble in the short time allotted. It is hoped to continue this project at some later date. Harry Hoogstraal, who was in charge of the program, and Chief Hospitalman Deaner K. Lawless conducted the field research on the shrew and later were sent back to the Sudan from Kenya by Captain Sapero to continue the project.

In addition to the elephant shrews, live guinea fowl and francolin partridges harboring blood pro-

A different type of tropical ulcer.

tozoa were sent back to the Naval Research Institute and are now being studied. These birds are the hosts of *Plasmodium* and *Leucocytozoon*. *Haematozoon* were found in ten reptiles. *Trypanosoma* were found in five types of animals, including the elephant shrew, and several other animals also contained filariae, which are being studied.

In western Equatoria observations were made on West African sleeping sickness (due to *T. gambiense*), blood filariae, and leprosy. A film on sleeping sickness, covering most of the epidemiology, clinical manifestations, and the ecological conditions under which *Glossina palpalis* thrives, was made in this region. Blood slides of the various filariae were obtained and stained on the spot to preserve them for use at the Naval Medical Center. In addition, collections were made of black flies, *Flebotamus*, tabanids, mosquitoes, tsetse flies, filth flies, etc. Hundreds of cases of leprosy, amoebic dysentery, hookworm disease, and the two common forms of bilharziasis, which is probably the worst scourge of Africa, were observed and photographed. A special study was made of the water snails that carry schistosomiasis, or bilharziasis, and comprehensive material was collected for the study of their taxonomy and distribution.

The press of other commitments in East Africa curtailed medical work in this area, which is so rich in interesting tropical diseases.

*Anthropology and archeology.* This program was conducted by Dr. Henry Field, who left the Sudan Party at Khartoum and flew to Nairobi to carry out anthropometric studies on one hundred and fifty Masai of Kenya. Further anthropometric studies were conducted in East Africa by Professor M. Mitwally, of Farouk University, Alexandria.

The rock drawings discovered at Abka by Oliver H. Myres, of Gordon Memorial College, Khartoum, were examined and photographed by Mr. Cope. Dr. H. B. S. Cooke and Professor Paul Deraniyagala, of the advance party, also examined and photographed these pictographs and were able to furnish Mr. Myres with valuable comparative information.

Twenty-seven men in Abka were measured and photographed, and Nubian words and phrases recorded. This was the first anthropometric data to be recorded on the Nubians in the Wadi Halfa area. In the Nubian desert between Wadi Halfa and Abu Hamed, several surface sites containing worked flint and quartz implements, and pottery, were discovered.

Thirty-eight members of the Rubatab tribe were measured at Abu Hamed, and flint implements were collected in the area. At Hagar el-Mirwa ("The Quartz Rock"), thirty miles south of Abu Hamed, scrapers, choppers, pounders, and flakes were collected. Quartz stone pounders and flint, rhyolite, and quartz flakes were accumulated forty-five miles south of Abu Hamed and near Wadi Selim, north of Atbara. Dr. Field and Mr. P. L. Shinnie, Sudan Commissioner for Archeology, and his wife discovered a Neolithic "gouge-culture" station near Omdurman.

Thirty-eight men of the Gumueya (Gumuia) were measured, studied, and photographed at Umm Disa near Khartoum.

### NORTHERN KENYA

*Vertebrate paleontology and archeology.* The Paleontological and Geological Section of the Northern Party, upon completion of work in the Eocene and Oligocene of the Egyptian Faiyum, proceeded directly south by truck convoy through the Sudan, across Uganda to Nairobi, Kenya. Included were Dr. Cooke, geologist (in charge); Professor Deraniyagala, paleontologist; Dr. Robert Denison, paleontologist; Captain George Russell, USA, geographer; M/Sgt. James Houle,

Keloid formations. (Photograph taken at Kapoeta.)

USMC, motor transportation; and David Cohen, scientific assistant. Geological and archeological studies were made en route.

Upon arrival in Kenya, the party refitted and made its way northward to the province of Turkana, which lies in the extreme northern part of the Colony, just west of Lake Rudolf. (Further paleontological investigations were conducted in East Africa by Professor G. H. Awad, of Farouk University, Alexandria, Egypt.) Base camp was established halfway between Lodwar and Ferguson's Gulf at the foot of a hill known to the local natives as Muruarett. During a brief reconnaissance in this area in 1932, Professor C. Arambourg had found vertebrate fossils of supposedly lower Miocene age in sediments interbedded with lavas. These beds, which the present party investigated more thoroughly, were of considerable interest because of the similarity of their fauna to that of the Miocene beds in the Lake Victoria region, which have yielded a number of fossil apes to Drs. L. S. B. Leakey and C. G. MacInnes.

In the immediate vicinity of Muruarett hill there were two small areas in which the sedimentary rocks were well exposed. Within these areas a distinctive dark-red marly tuff was found to be the most productive, the other horizons being nearly barren. This productive series appears to consist almost entirely of material derived from volcanic ash, carried by shallow waters and laid down under deltaic conditions. The specimens collected were mostly surface finds of fragmentary or isolated skeletal parts, although occasional more nearly complete specimens were discovered, including one partially articulated skeleton. Intensive and detailed prospecting of these two small areas produced the major part of the collection from Turkana.

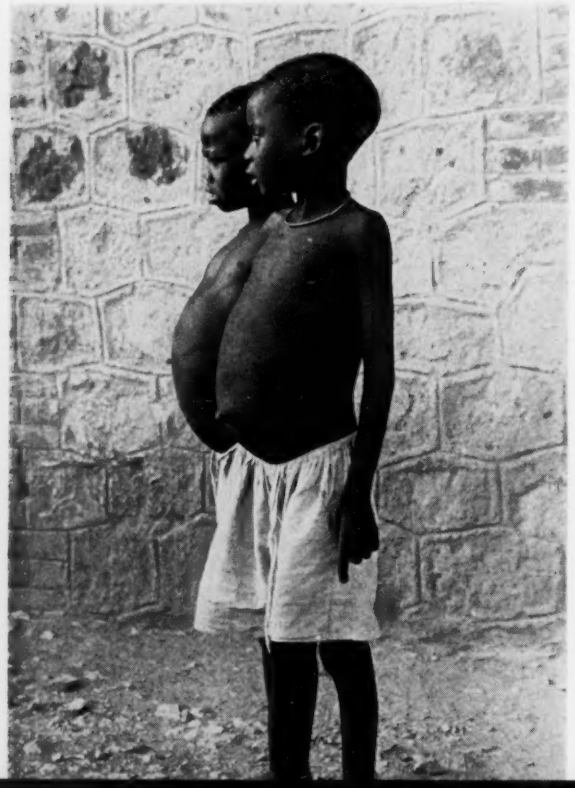
Madura foot, result of infected thorn wounds.

Reconnaissance prospecting trips were made, particularly within twenty miles of camp. Similar sediments interbedded with lavas were found, but they were for the most part unproductive. Only the region around Muruarett hill produced any sizable collection. At another locality below the peak known as Lothidok, a huge turtle, approximately $4.5 \times 6.5$ feet, was discovered and partially uncovered, but it was found impractical to move it because of the logistic problems involved.

Notable among the specimens from Turkana were fragmentary jaws of two apes, the first to be discovered in this region.†

In general, the first fragment emphasizes the relatively close kinship of the fossil apes named *Pliopithecus* from the Miocene of Europe, *Dryopithecus* from the Miocene and Pliocene of Europe, *Sivapithecus* from the Pliocene of India, and *Proconsul* and allied genera from East Africa. It probably represents one of the smaller species of the *Proconsul* group, but until closer comparison with these forms can be made, a more exact de-

† The writer wishes to express his appreciation to Professor William K. Gregory, American Museum of Natural History, for a detailed analysis of these two specimens, which will be published later.



Children of the southeastern Sudan, showing evidence of hydatid disease.

termination seems inadvisable. The second fragment strongly recalls the corresponding parts in *Proconsul africanus* Hopwood.

Other fossil mammals included antelopes, pigs, elephants, carnivores, and rhinoceroses. Aquatic forms in the fauna were represented by crocodiles, turtles, gastropods, and pelecypods.

Three human skeletons from much later deposits were discovered near camp. The older human burial was associated with microlithic tools and occurred in a river terrace deposit, which has been tentatively identified as Mesolithic in age. The younger skeletons found buried under rock mounds had no artifacts with which to date them, but they are undoubtedly ancient. Professor Deraniyagala, who discovered and excavated two of the skeletons, first drew my attention to the possibility that several of the mounds of boulders situated around the base of Muruarett hill might represent Stone Age burial tumuli.

Advanced cases of leprosy in the Sudan.

Human burials covered by stone mounds occurred at many points on the hundred-meter terrace, but not at much lower levels, suggesting that the mounds were not very remote from the lake shore at the time they were built up.

Geological reconnaissance was carried out over a wide area and served largely to confirm the excellence of the work conducted by Arambourg in 1932. There seems little doubt that rift faulting and folding has affected the whole region. The main escarpment of the Rudolf rift on the west side is thought to be concealed by Pliocene and later lake deposits. Raised beaches occur about one hundred meters above the present lake level and contain a few stone implements. Large numbers of microlithic tools occur on the surface. Study and description of implements from Turkana are being undertaken by Dr. L. S. B. Leakey, curator, Coryndon Memorial Museum, Nairobi.

A number of very black and phosphatized fish vertebrae were found in the beach gravels at Ferguson's Gulf. They closely resemble the material from the Omo beds of Abyssinia at the extreme northern end of the lake. Their occurrence a hundred miles south of the southernmost outcrop near Todenyang is suggestive of a former greater extent of the Omo beds (Lower Pleistocene), which are probably concealed by younger deposits. It is possible that further exploration will reveal some outcrops at isolated areas around the periphery of Lake Rudolf.

The region north of Lodwar to Lokitaung on the Abyssinian border was investigated. Although the series of volcanic rocks is well exposed throughout this region, no accessible areas of fossil-bearing sediments were found. Near Namaraputh fort small exposures of the Omo beds were examined, and a few mammalian and fish fossils were collected.

The story of the remainder of the University of California African Expedition, which included investigations in Kenya, Zanzibar, Uganda, Tanganyika, the Belgian Congo, Northern and Southern Rhodesia, South Africa, Mozambique, South West Africa, and Madagascar, will appear in a forthcoming issue of The SCIENTIFIC MONTHLY.

Photographs on page 264 by H. B. S. Cooke; top, page 265 by C. D. Evans; all others by Harley F. Cope, USN.

Guinea worm emerging from left wrist. Another is about to emerge from right breast. All tribes in this area practice the elaborate tattooing shown here.

# SCIENCE ON THE MARCH

## THE METEOROLOGY OF OTHER PLANETS

THERE has been a recent revival of interest among astronomers in the problems of the physical constitution of the planets, which had become overshowed by the very rapid advances in stellar astronomy. It is now realized that the powerful methods of astrophysics, both observational and theoretical, can be applied to the planets with great success.

Thus G. P. Kuiper, director of the Yerkes and McDonald observatories, has begun an attack on a broad front upon the problems of the planets and their satellites. His observations of the infrared spectrum of different parts of the planet Mars have shown conclusively that its polar caps consist of water (probably in the form of hoar frost). He finds also that the green areas on this planet cannot be due to higher forms of plant life as had often been supposed, since chlorophyll is absent. Also at the Yerkes Observatory, S. Chandrasekhar has achieved a detailed theoretical solution of the intricate problem of the illumination of planetary atmospheres. A third development is the cooperative program undertaken by the Lowell Observatory and the U. S. Weather Bureau, which has shown that modern meteorological theory can be fruitfully applied to the atmospheres of the other planets.

A very interesting new approach to the study of planetary atmospheres has been opened by the German astronomer Wilhelm Becker. His original intention was to determine whether the brightness of the sun varied appreciably. Since the direct determination of the apparent magnitude of the sun is technically exceedingly difficult, Becker instead considered the brightness of the planets, which are much easier objects of photometry. Accordingly, he collected, and reduced to a uniform scale, all measurements made since 1850 of the brightness of the planets Mars, Jupiter, Saturn, Uranus, and Neptune. All these observations were corrected for the effects of the varying distances of the planet from the earth and the sun, and for the effects of phase.

This laborious compilation uncovered unexpected phenomena of great interest. All five planets showed conspicuous slow changes in brightness. These changes were unquestionably real, as independent series of measurements by different observers showed the same variation in planetary brightness. Nevertheless, these variations could not be attributed to the solar variability, for the planets did not increase or decrease in brightness simultaneously. Clearly, the cause must lie in the atmospheres of the individual planets.

Consider the case of Mars. For intervals of several decades, this planet remains at constant brightness, but will then brighten by 0.5 magnitude, and in a few years fade again to its usual state. This behavior is just what would be expected if the usually clear atmosphere of Mars would from time to time become hazy for a few years; the greater reflecting power of the haze, as compared with the relatively dark surface of the planet, would cause a temporary increase in the brilliance of Mars.

The behavior of Jupiter is quite different. This planet waxes and wanes rhythmically in brightness, with a range of 0.3 magnitude, periodically in a cycle of twelve years. It is noteworthy that certain cloud features in Jupiter's atmosphere undergo periodic alterations in color synchronously. Thus, the English astronomer A. Stanley Williams showed that the equatorial zone of Jupiter varies between red and white in a twelve-year cycle. Jupiter is brightest when the equatorial zone is reddest. The cause of these interlocking changes is obscure; the near equality of twelve years with both the length of the sunspot cycle and the period of Jupiter's orbital revolution around the sun offers two hints, both of which may prove misleading.

The light variations of Saturn are quite unlike those of the two planets just described. Saturn usually remains at maximum brightness, but at irregular intervals, of the order of about a decade, will decline in light by about 0.3 magnitude, and regain its former brilliance after two or three years. This appearance is much as if the bright cloud surface of Saturn were liable to a temporary gray veiling. It is a noteworthy circumstance that the appearance of brilliant short-lived white spots on Saturn in the years 1877, 1903, and 1933 has in

all three cases occurred when Saturn has been abnormally faint.

For Uranus more than 4,400 observations of brightness made between 1864 and 1948 were examined by Becker. This richness of material is fortunate, for the case of Uranus turns out to be more complicated than for the other planets. First there is a very well-marked eight-year periodicity in which Uranus varies by 0.3 magnitudes. Underlying this is a very slow change in brightness, which arises from the spheroidal shape of the planet. Uranus is unique among the planets in that its axis of rotation lies nearly in its orbital plane. Accordingly, when in 1903 and 1945 its pole pointed toward the earth, the largest cross section of the planet was presented to a terrestrial observer, so that the planet appeared relatively bright. This light variation shows two maxima and two minima during the eighty-four-year orbital period of Uranus. Becker was able to calculate from the observed amplitude of these brightness changes how great the polar flattening of Uranus is; his figures are in very fair agreement with those from the direct micrometer measurements of the shape of the planet.

The intrinsic variations in the brightness of the outer planets are to be counted among the most significant discoveries of recent years in the astronomy of the solar system. Although these phenomena still await detailed interpretation, it is evident that these changes arise in the planetary atmospheres. Accordingly, the brightness of a planet is to be regarded as an index of the meteorological conditions in that planet's atmosphere.

Becker has raised the interesting point that it is entirely reasonable that the brightness of the earth, as seen from another planet, may vary as the amount of cloudiness in our atmosphere changes. And, as he remarks, in this connection the long-period terrestrial climatic cycles suggested by Brückner and others take on a new significance.

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## BUILDING MENTALLY AND PHYSICALLY STRONG HUMAN BEINGS

According to authoritative reports from all over the world, more than half the people on the earth are existing on marginal rations, or just enough to keep them alive. If a state or nation is to be strong, its people must be strong, mentally and physically. The human body will produce such a result if, from birth, children receive food containing all the necessary elements.

The composition of the human body is less than 6 percent mineral, the principal minerals being phosphate and lime. When children get a marginal ration from birth, the first deficiency easily determined is in the bones of the hands and feet. Figure 1 shows the hand of an eight-year-old boy who has never had enough to eat; Figure 2, the hand of a normal boy who has had the proper food from birth. Note that some of the bones are missing and some are small and underdeveloped in the hand of the boy who has received only the marginal ration. Children on such rations will show definite physical and scholastic deficiencies, and if we attempt correction by feeding a well-balanced ration, authorities tell us it takes two to four years to show any visible results.

Even though the analysis of the composition of the human, or animal, shows him to be less than 6 percent mineral, what will happen when available minerals give out? When bromine was wanted to produce tetraethyl lead to stop the knock in gasoline, William J. Hale told us to go to the ocean. When a metal lighter than aluminum was needed for airplanes, Hale again said go to the ocean, and get magnesium. Now other elements are being taken from the ocean, and it is claimed that they are cheaper than those taken from the earth. A combination of chlorine, soda, and some other elements is called "sea soil," which may contain the elements necessary to complete the cycle in agriculture. Perhaps this will enable us to grow plants that will supply even the trace elements that are so vital if a plant is to produce perfect food.

Table 1 gives an analysis of a product (not "sea soil") taken from the ocean and now on the market. It will be seen that it contains the elements and minor elements. The sea contains all the elements in such abundance that they cannot be exhausted.

When the world gets hungry, it cries for protein foods and for fats. The University of Florida Ex-

TABLE 1

| | Percentage |
|---|---|
| Mg as MgO | 82.5 |
| Ca as CaO | 11.3 |
| Cl as NaCl | 1.1 |
| $SO_4$ | 1.86 |
| $SIO_2$ | 1.91 |
| $R_2O_3$ | 2.65 (corrected to 1% or less) |
| Mn | 0.097 |
| $P_2O_5$ | 0.109 |
| F | 0.039 |
| B | 0.024 |
| Br | 0.004 |
| K | 0.030 |
| Al | 0.25 |
| I | 0.00005 |
| Cu | 0.0003 |
| NI | 0.0002 |
| CC | 0.00005 |

periment Station has shown that just one summer legume (Fig. 3) has returned to the soil 104 pounds of organic nitrogen per acre and has repeated this for four years. Commercial organic nitrogen fertilizer would cost at least $10.00 per unit, making nitrogen cost fifty cents per pound in terms of protein food. An acre of this legume will return at least 640 pounds of proteins. When our soils have lime, with a reasonable amount of phosphate and potash added, a favorable condition is created for growing legumes, and by inoculating the seed when they are planted, little nodules which form on the roots will house the organisms that fix the atmospheric nitrogen. These organisms can be

Fig. 1. Effects of malnutrition on bones of the hand of an eight-year-old boy.

Fig. 2. Bones in the hand of a normal eight-year-old boy.

bred like plants, so that strong organisms take in more nitrogen from the air than weak ones.

The nitrogen-fixing organisms vary according to the different strains of legumes. They multiply within the hour. On a good stand of legumes, raising four plants per square foot, there would be on an acre, according to one microbiologist, 52,272,000,000,000 of such organisms. The amount of nitrogen above every acre is 95,256,000 pounds.

The southeastern section of the United States is one of the few places in the world that has phosphate and lime at its door, heavy rainfall, an abundance of sunshine, and soil and plant activity over the entire twelve months of the year. In Florida, the nitrogen-fixing organisms work night and day, twelve months in the year, in contact with atmospheric nitrogen under pressure. In some sections of the country, there is less than six months of soil and plant activity, so enough food must be harvested during the active months for the remaining months.

Knowing what we do, is it not reasonable to suppose that the South could furnish more of the principal elements—phosphate, lime, and atmospheric nitrogen—in abundance than any other region? And doesn't it stand to reason, since we have twelve months' activity of the soil, that careful research by chemists, physicists, microbiolo-

gists, and plant breeders could result in great contributions to the world's food supply? Thus the South could not only increase the mental and physical strength of future generations but do it faster than any other section of the country.

Progress in every field follows broad, intensive, practical, scientific research. Step by step, research will point to the correct course. In my opinion, however, the proper and necessary scientific research is not now being carried on.

One reason this problem appeals to me so strongly is my experience in Germany something over fifty years ago, before I came to Florida. Contact with the average German impressed me with his superior mental and physical strength. Undoubtedly the Germans were at that time the strongest people in the world. You needed no statistics—you simply went from Germany to France, from Germany to Spain, or from Germany to Italy, and you were conscious of the difference. When I arrived in Florida, one of my old associates was operating the first large phosphate business in that state. His company owned its own terminals in Jacksonville, mining high-grade phosphate, running 75 percent bone, phosphate, and lime. Every pound of this phosphate was loaded aboard ships and sent to Germany. Up to the time of World War II Germany was getting nearly one third of the phosphate produced in Florida.

When I read reports from other states—Ohio, Michigan, Wisconsin, and nearly all the others—they show deficiencies in food. We are shipping billions of pounds of food to Europe—which is fine, but we are also shipping soil fertility, and rapidly approaching a period when our entire population may be on a marginal ration. There is a great deal of talk about this, but little is being done.

What I am trying to do in a small way in Florida is to balance the soil so as to produce a perfect animal, for I believe the food from such soil

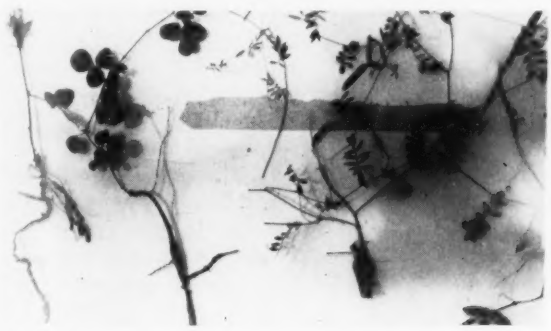

Fig. 3. Some of the legumes that grow wild in Florida's acid flat woods soils.

Fig. 4. Steak from a calf barely six months old.

will produce future generations of perfect humans. We have a little acreage where livestock have been grazing without added food for five years. We have never fed them. Figure 4 shows a steak from one of these animals at six months of age. This livestock can be improved by breeding, and we can greatly improve and enrich the soil, particularly by scientific research in the naturally-occurring legumes and the nitrogen-fixing organisms.

When we learn more about how to use the elements in the air, in the earth, and from the sea, learn to breed plants and microorganisms, we should be able to produce enough good food to satisfy the present world population, as well as expected increases in population, increase soil fertility, and at the same time build stronger human beings, both mentally and physically.

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# BOOK REVIEWS

## TWO NATURALISTS SPEAK TO STUDENTS OF THE SCIENCE OF BEHAVIOR

*George Ellett Coghill, Naturalist and Philosopher.* C. Judson Herrick. 280 pp. $5.00. University of Chicago Press. Chicago.

BOOKS are news. Noteworthy news when a distinguished naturalist and philosopher writes at length about another distinguished naturalist and philosopher with whom he was intimately associated over a period of forty years. C. Judson Herrick, as a labor of love and particularly as a service to scientific youth, has prepared a most unusual volume of biography, commentary, and dialogue concerning the life and work of George Ellett Coghill. Indeed, the volume is really three books in one, each book quite distinct in subject matter and method of treatment. They constitute a unique memoir, and incidentally afford many pleasing autobiographic glimpses of their author, whose devotion to the science of behavior has paralleled that of his subject.

The construction of this three-way volume is interesting. Book One is a sympathetic, intimate biography of Dr. Coghill, a personal history of his scientific career, not omitting disappointments and frustrations, but emphasizing his pertinacious adhesion to research goals. Book Two is a carefully wrought analysis of Coghill's scientific method and of his contributions to the interpretation of processes of growth in their relation to psychological processes. The treatment here is appropriately made somewhat genetic by tracing the growth of principles chronologically. Principles matured slowly in Coghill's mind, and bore fruit in philosophical reflections, which, however, were formulated in only a fragmentary manner. Book Three rescues these fragments and places them in an arresting frame of reference, using the literary device of the Socratic dialogue. The reader is invited to "imagine the two of us, George Coghill and I, lounging comfortably before an open fire and letting the talk drift at will over the whole range of our interests." Before the embers die the talk touches and even penetrates age-old problems of structure and function, the psychoorganismic individual, space, time and space-time, purpose, causality, and freedom.

These three books are by no means unrelated, and are woven into an interpretive whole. Herrick takes the position that Coghill's work is a singularly integrated scientific product and that to estimate its import one must know the man whose life it expresses. Herrick has a thesis:

> The traditional code of science—that is, the objectives sought and the methods of investigation—cannot satisfy the requirements of our critical times, and this is why science has failed to measure up to the opportunities and obligations before it. . . . The time has come to recognize the humanistic significance of science—so-called pure science, I mean—and to adjust our practice accordingly.

It is this outlook upon modern science which will make Herrick's book peculiarly suggestive to students of behavior and to young scientists who have to reckon in some measure with concepts in the fields of theoretic biology, psychology, and philosophy. The book does not preach; but it is replete with factual data, which provide clue and orientations. It is the kind of book that encourages reflective thinking. Take Chapter 16, for example. In less than seven pages and in thirteen cogent theses there is presented an analytic summary of the processes of growth, as conjointly disclosed by the lifework of Coghill, the anatomist, and of Herrick, the comparative neurologist. Here is food for active thought; the same sort of thought that set Coghill going on his long and productive career of research and teaching.

"Even as a undergraduate student," says Coghill, "I became aware that the rational approach to the kind of psychological information I wanted, lay through the physiology of the nervous system. Obviously, also, the physiology of the nervous system must be approached through its anatomy, about which I knew nothing." And so for some thirty years he made minute studies of the genetic and functional histology of *Amblystoma*. For a long period he worked in relative isolation, and papers fundamental to psychology were reported to fellow-anatomists. In 1928, University College, London, and colleagues in the Institute of Anatomy invited Coghill to deliver the three lectures that appeared in a volume entitled *Anatomy and the Problem of Behavior*. This slender volume bids fair to become a classic. Englishmen may rightly claim that they revealed Coghill to American science. Herrick's book continues this revelation.

The titles of the basic lectures are worth recalling: *Lecture I.* The Development of Behaviour and its Anatomical Explanation in a Typical Vertebrate; *Lecture II.* Dynamic Antecedents of Neural Mechanisms; *Lecture III.* Growth of the Nerve Cell and the Interpretation of Behaviour. The final lecture dealt with learning in terms of behavior, the limitations of the neurone concept, conditioning, individuation, "forward reference," Gestalt, and growth as the creative function of the nervous system. The mere enumeration of such topics indicates how extensively Coghillian principles have in the past two decades pervaded the domains of biology and psychology.

Coghill concluded his London lectures with a characteristic comment which was philosophic, but which grew out of prodigious research:

The real measure of the individual, accordingly, whether lower animal or man, must include the element of growth as a creative power. Man is, indeed, a mechanism, but he is a mechanism which, within his limitations of life, sensitivity and growth, is creating and operating himself.

The student who is seeking his own measure, and who is wondering about the measure of mankind, will be repaid by a reflective reading of Coghill and of Herrick on Coghill.

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## FAUNAL STUDIES

*Birds of Concord.* Ludlow Griscom. 340 pp. Illus. $5.00. Harvard University Press. Cambridge, Mass.

IN THIS, the second of a series of faunal studies from areas of Massachusetts, Ludlow Griscom has excellently contrasted the records of William Brewster, noted early member of the Nuttall Club, with the detailed studies of the present generation. The area studied centers around the Sudbury and Assabet river valleys, which join at Concord to form the Concord River. Several basic factors are considered by Griscom in his study of the local avifauna of the Concord region. The geology and climate which condition the flora and control the growing season and composition of the flora are considered first. The flora comes next. Land birds of eastern North America occur only where there is vegetation. Following the vegetation, which supplies shelter and food, the birds themselves are considered. Regarding them, Griscom says, "Whatever their requirements and limiting factors are, these birds were conditioned long before the Concord region, in any modern sense, existed." Those birds which occur in the Concord region are the ones that find conditions from favorable to just within the limits of their tolerance. The white man and his civilization are considered as basic factors affecting population trends, as is the power of a species to take advantage of changed or changing conditions. Finally, long-range climatic changes and extremes in climatic cycles are considered in setting the stage for population trends in birds. Each of these basic factors is well presented and supported by local illustrations, factual data, or other evidence.

Having completed this background, Griscom treats birds as a class. This section includes a discussion of temperature tolerance, food requirements, habitat preferences, reproductive capacity, and other features, such as mortality, distribution, and adaptability. Griscom's concluding proposition, based on his review of early studies, consideration of the basic factors and of birds as a class, is that "an absolutely static population of all species of birds for any length of time is a biological impossibility and contrary to common sense!"

Following a short section on fluctuations in numbers of animals and birds, which is filled with factual data, population declines and increases of the Concord region are treated. This is the most valuable section in the book. To illustrate, this section contains data on the American egret and wood duck, that have been recorded periodically in the Concord area since 1650 —three centuries of observation and information describing population trends.

A systematic list of birds of the Concord region completes the volume. It contains sixteen photographic illustrations, all of which were obtained from the National Audubon Society.

*Birds of Concord* is a scholarly contribution. It should be of great interest to biologists and ecologists, as well as to ornithologists and bird lovers. It is unfortunate that a more appropriate title was not selected for this valuable volume.

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## HEREDITY VS. ENVIRONMENT

*The Nature-Nurture Controversy.* Nicholas Pastore. xvi + 213 pp. $3.25. Columbia University Press. New York.

RIGOROUSLY objective as biologists and psychologists may try to be, the more careful and sensitive ones realize that they tend to be influenced in what they see, in how they weigh facts, and in what they conclude by their own cultural backgrounds. Comparative cultural anthropology and the sociology of knowledge promise to help them and other scientists to understand better and to compensate somewhat for the idea systems they took on as children.

Pastore's study of the nature-nurture controversy is an effort to show, through a detailed analysis of the writings of twenty-four scientists who made their major contributions in 1900–1940, how their ideas on nature-nurture correlate with their liberal or conservative social ideas. This is a difficult task. The list of twelve hereditarians and twelve environmentalists is brief, careful, but of course subject to criticism. A longer list would have presented, among other problems, the complexities of adequate analysis. The author mentions a number of other individuals who were considered and dropped either "because they did not express themselves sufficiently extensively to make their inclusion worthwhile" or "because their positions were quite similar to those who have already been discussed." None, he says, was omitted because of sociopolitical outlook.

Pastore's use of terms is a common-sense and workable one. He applies the term "conservative" to those who are "pessimistic with regard to the potentialities of the average person or who [are] critical of attempts to broaden the participation of the citizenry in governmental affairs. Acceptance of the *status quo* is also taken as indicative of a conservative orientation."

He characterizes as "liberal" those who believe "in the necessity of change" and who are favorably disposed "toward the possibilities of the average man and toward the democratic concept." The "radical" are, of course, interested "in the necessity of thoroughgoing change in social, political, and economic institutions."

In terms of these definitions, Pastore found that eleven of the twelve environmentalists were either liberals or radicals, and eleven of the twelve hereditarians were conservatives. The exceptions in the two groups were, respectively, John B. Watson and Lewis M. Terman. Pastore therefore concludes that "the sociopolitical allegiances of the scientists were a significant determinant of their position on nature-nurture questions." He also points out, from his extensive survey of the literature, that the "nature-nurture controversy, qua controversy, has been sustained by the conflicting social philosophies of the scientists."

Free scientists in the United States can behold, understand, and lament the spectacle of a politically reinforced nature-nurture orthodoxy which has developed and has been promulgated in the USSR. But it is all the more important for free scientists to learn how to understand their own social preconceptions and those of their fellows. They can only thus keep their cultural backgrounds from weakening their ability to see and to understand. Pastore's work is a useful contribution to the development of the sociology of knowledge as a tool for the further development of scientific method.

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## SUGAR'S VERSATILITY

*Sugar: Its Production, Technology, and Uses.* Andrew Van Hook. ix + 155 pp. Illus. Ronald Press. New York.

THE magnitude of the world sugar industry and the importance of sugar in our diet make a book on this commodity a very necessary addition to popularized science. This book is brief, with a reading time of three hours or less, and it attempts a review of the production of sugar cane and sugar beets, the processing of these crops to refined sugar and by-products, and the world production and trade in sugar. Space is also given to the chemical nature of sugars and the historical development of their use and manufacture. It seeks to present a general picture for the beginner and others who wish to become informed about the sugar industry.

The difficulties of presenting so many chemical, technical, and statistical facts in terms understandable to all were not fully overcome. Definitely the reader will be impressed by the complexity of the structural chemistry of sugars, by the lengthy procedures needed to prepare commercial white sugar, and by the importance of sugar historically and in world trade. It is also certain, however, that he will be somewhat confused. This will be due partly to the lack of unity in the material included under specific headings and to the numerous digressions. One example is the inclusion of a discussion of corn-sugar manufacturing in the chapter on Production—Cane. Many of the fine illustrations are not placed near the subject matter with which they are associated.

It may be a matter of personal bias, but probably many others will also feel that too much space is given to the world production and trade statistics and too little to mechanical harvesting, that there is too much stress on the application of the ion-exchange process and too little on the established improvements brought by continuous diffusion, and that the ten-year-old glutamic acid by-product industry is mentioned too briefly, whereas the undeveloped possibility of pectin manufacture is emphasized. We also note the omission of kraft paper and synthetic resins as products prepared from bagasse.

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## NEW OUTLOOK ON SCIENCE

*Philosophy of Mathematics and Natural Science.* Hermann Weyl. x + 311 pp. $5.00. Princeton University Press. Princeton, N. J.

THE greater part of this book comprises a translation, with alterations, of Hermann Weyl's contribution to R. Oldenbourg's *Handbuch der Philosophie* of 1926, the time "when the theory of relativity had reached completion and the new quantum mechanics was just about to rise" (p. vi). Six added essays "are more systematic-scientific and less historico-philosophical in character than the main text." They deal with the most recent developments in mathematics, physics, and biology.

As a presentation of the new outlook on science and the world, Weyl's book may provoke comparison with Eddington's *The Nature of the Physical World* and *New Pathways in Science.* Although some of the discussions refer to the same subject, and many of the conclusions are similar, the basis and the range are very different. Where Eddington causes sparks to fly between highly charged new concepts and earthy conventional convictions, Weyl sets the gems of newly gained insight into the solid grounds of mathematics and philosophy. These grounds are not easily accessible. For the mathematical parts in particular, the reader will have to bear in mind that "one of the principal tasks of this book should be to serve as a critical guide to the literature listed in the references" (p. vi).

In connecting the most advanced thinking in mathematics and physics with that of the past, the author shows that time is as necessarily a dimension in our thinking as in the brave new world of the four dimensions. From Plato to Newton and through Leibnitz and Descartes to Helmholtz and Husserl, our

thoughts have been formulated, and even the much-maligned philosophy of Schelling has concepts which, like his "shapeless fluid," are relevant to what we have just found.

Problems that haunted philosophy for centuries find their solutions in the new science. It teaches to keep "open into infinity . . . the ordered manifold of possibilities which can be generated by a fixed process" (p. 38). The rules of isomorphic mapping clarify the relationship of things in themselves to phenomena. Absolute space is reduced from a problem of transcendental idealism (Kant) to a combinatorial fact. The binary gradation into a priori and a posteriori is replaced first by a ternary one (p. 135) and, finally, by "a rich scale of gradations of stability" (p. 154). We start with theories which are only roughly correct and continue to improve them on the basis of experiments, although "trust in induction, if it is to be justified, can only be justified by the principle of induction itself. But trust in the world and in oneself is in no need of justification; it is the natural attitude of the mind's life, especially as it manifests itself in thetic acts of reason" (p. 163 f.). Our primitive combinatorial schemes may not be adequate, yet it seems best "to make the picture itself, however limited its value, as definite as possible." In doing so, we can follow the advice of Nicolas Cusanus (p. 274). Scientific construction seeks the explanations in an "outer" realm of objects and in immanent laws, not in origins. There is another approach, that from "within;" "what is darkest for theory, man, is the most luminous for the understanding from within; and to the elementary inorganic processes, that are most easily approachable by theory, interpretation finds no access whatsoever." A kind of exclusion principle seems to exist here. "Understanding, for the very reason that it is concrete and full, lacks the freedom of the 'hollow symbol'" (p. 284).

The use of symbols leads to the construction of theory which, in mathematics and physics, is universally compelling. The process of such construction relies on the unity of nature, but it does not overcome the logical paradoxes which arise in old and new forms. Hilbert's new attempt of solving "once for all" the problems of mathematical accuracy had the effect of bringing new paradoxes to light.

It is the obvious permanence of paradoxes which makes philosophical study of mathematics and physics necessary. If, stimulated by Weyl's lucid exposition, we turned this statement around and asked whether philosophical study did not make paradoxes necessary, we could find the answer in this book. In all our paradoxical and ironical (see example on p. 202!) situations, we still have the "trust" which needs no justification, and we have the experience which shows that when we form final answers prematurely, nature compels us to recognize a more profound harmony (p. 159).

In a time of oppressive departmentalization in science, the need for synthesis has come to be strongly felt. Weyl presents a most impressive example of scientific synthesis. It is gained by unrelenting search of facts and meanings in the system which must remain "open to infinity"—open, also, to immediate further effort. That questions arise from the difficult attempt at synthesis is, therefore, within its purpose.

A different set of questions pertains to the translation, particularly because of its general excellence. The German words *erkennen* and *Vorstellung* have no direct and sufficiently poignant literal counterpart in English. *Erkennen* means the thorough, final knowing which "to perceive" expresses perhaps better than "to cognite." *Vorstellung*, in most cases, is less accurately rendered by "presentation" than by "ideal image."

The main question, however, which Weyl's book may cause us to ask is this: Should we not be amazed at those who claim that all this thinking about foundation and synthesis is not practical since it is not practiced in business and politics? How many grievous mistakes are made in these practical decisions, and how many could be avoided by applying more science and philosophy?

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## THE ROUND EARTH ON FLAT PAPER

*The Story of Maps.* Lloyd A. Brown. xix + 397 pp. Illus. $7.50. Little, Brown. Boston.

TO MOST people, maps are fascinating. This is probably related to the very human curiosity of wondering and trying to learn something about the earth we inhabit. The impulse to portray graphically the immediate environment, or the world as a whole, is encountered at all levels of civilization, and at all stages of history.

The Babylonians inscribed crude maps on clay as early as 2300 B.C. Modern map making, in contrast, is a highly technical process involving precision instruments and specialized techniques. The steps in the development and evolution of these tools and methods of cartography, and the personalities and nations engaged in mapping in the world during the past 4,000 years, are interestingly described in *The Story of Maps.*

Determining the size and shape of the earth was a cartographic contribution of the ancient Greeks. They also provided answers to the questions of how much of the world was habitable, and how much of it was actually inhabited.

Claudius Ptolemy, all-time cartographic great, put into practical use many of the ideas advanced by the Greek geographers. Working in Alexandria in the second century A.D., "he demonstrated more clearly than any of his predecessors, and in greater detail, the numerous feasible methods of applying the facts of astronomy to the study of the earth; he systematized the mapping of the earth's surface, and in his writings set forth the principles and techniques

employed by modern geodesy." Ptolemy's atlas set the cartographic standard for almost 1,500 years.

Scientific map making was eclipsed, during the Middle Ages, by the fanciful and illogical scriptural maps. But even the Dark Ages made their contribution to world mapping, for the religious pilgrimages and Crusades stimulated trade and exploration. More navigation and travel called for better charts. Cartographers obliged with gaily decorated, and amazingly accurate, portolan charts.

Three significant developments during the latter half of the fifteenth century stimulated new interest in map making. Printing was invented, Ptolemy's *Geographia* was revived and made generally available in printed form, and Columbus sailed westward to discover a new world. The result was a "golden age" for cartography during the sixteenth and seventeenth centuries, led by such map-making immortals as Martin Waldseemüller, Gerard Mercator, Abraham Ortelius, Jodocus Hondius, Christopher Saxton, and Willem Blaeu.

The eighteenth century was characterized by great advances in scientific methods of surveying and mapping. New instruments made possible more precise determination of latitude and longitude and consequent greater map accuracy. Large-scale topographic surveys on a country-wide basis were carried out. With general acceptance of a universal prime meridian and uniform standard of time around 1890, "mankind was mentally prepared and scientifically equipped to think and act in terms of global cartography."

*The Story of Maps* might better be called "The History of Map Making." The emphasis definitely is on the past, and upon the techniques and processes of mapping rather than upon the maps themselves. There is but brief mention of the new methods, instruments, and techniques for mapping devised during the past half century and particularly during the recent war years.

The book is profusely illustrated with portraits of the great cartographers, pictures of instruments, and reproductions of old maps. Unfortunately, the illustrations are scattered at random, and only by chance do they appear adjacent to the text to which they are related.

Such a comprehensive history of map making has not previously been attempted. As one explanation for this lack, Brown quotes from Robert Hooke, seventeenth-century physicist, as follows: "There are but few who, though they know much, can yet be persuaded they know anything worth communicating."

Readers of this book will agree that the author knows much about his subject. They will rejoice, moreover, that he was persuaded to communicate to others the results of his extensive research and study, and of his personal experiences with maps.

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## BRIEFLY REVIEWED

*Syphilis: Its Course and Management.* Evan W. Thomas. xix + 317 pp. Illus. $5.50. Macmillan. New York.

DR. EVAN THOMAS has a very active part in several syphilis treatment programs. He is a recognized scientist, as well as an excellent clinician. His book emphasizes treatment, but, like other such treatises, must also take up diagnostic procedures and clinical findings in order to make the course of the disease during and after treatment a complete picture. There is little to dispute throughout the early sections of the book that deal with infectious syphilis or latent syphilis. The types of syphilis that have not yet been studied for long enough periods of time or in great enough numbers to draw any sweeping conclusions after penicillin therapy, such as cardiovascular syphilis, neurosyphilis, interstitial keratitis, and optic atrophy, are handled in a manner that should satisfy the skeptic as well as the enthusiast. There is no one better qualified than Dr. Thomas to write a text on syphilis, its course, and management, and any reader interested in the modern treatment of this disease will find his book the most up-to-date one of its day.

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*Social Psychology of Modern Life.* (Rev. ed.) Steuart Henderson Britt. xvi + 703 pp. Illus. Rinehart. New York.

IN THIS volume, a particularly well-informed and versatile psychologist gives students and laymen a good idea of the breadth of the field of social psychology. A revision of a 1941 publication, the new edition incorporates considerable recent research and experimental data. Following some general introductory material, the author treats many diverse aspects of the impulses, ideas, attitudes, and behavior of people in group situations ranging from the intimate home setting to the crowd, and to the more structured larger group. Included among the topics discussed are group reactions, dominance, and leadership; the impact of institutions like the family and religion; social conflict in delinquency, discrimination against minority groups, nationalism, and war. Britt concludes his presentation with a timely criticism of ivory-tower scientists who are content merely to observe without assuming responsibilities of leadership or even an active role in correcting flaws, weaknesses, and inequalities in the social structure. A detailed list of citations, texts, and related sources is provided in three appendices.

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# CORRESPONDENCE

## A FALLACY UNDERLYING GARRETT'S USE OF THE DATA OF THE ARMY ALPHA AND BETA TESTS—A COMMENT

The Army tests were instruments designed by a committee selected from the ranking psychologists of the period in order to classify men efficiently for Army purposes in World War I. Utilizing the techniques then available, this committee of psychologists constructed a series of tests intended to measure the native intelligence of individuals. Close to 1,800,000 soldiers were tested and classified. The results of this vast testing program, quite useful to the Army, were immediately seized upon by scientists, educators, and journalists in order to strengthen or advance some particular scientific, educational, or political aim. Was heredity more important than environment? Did individuals drop out of school because of defect of native intelligence or because of some social and economic disadvantage? Was democracy a failure? Were the new immigrants worthy of American citizenship? Were there any significant differences among individuals belonging to different nationalities and physical types? These were some of the questions underlying many discussions in the turbulent postwar period, discussions which involved the interpretation of the results of the Army testing program. Today these questions are rarely raised—at least not in the black-and-white fashion that formerly characterized their phrasing—nor are the Army test results generally drawn upon in psychological discussions. There are some important exceptions, however. Garrett, in a SCIENTIFIC MONTHLY article, uses the Army test results as partial evidence for the intellectual inferiority of the average Negro.[1] Benedict and Weltfish, on the other hand, in their pamphlet *Races of Mankind*, use the Army test results as evidence for Negro equality.[2] The question is: Is the intelligence of the average Negro equal to that of the average white person?

The purpose of this brief comment is to call attention to certain features of the Army tests that are relevant to the discussions of comparative intelligence.

According to an assumption of test methodology, a test should be constructed in such a manner as to yield a series of scores which is continuous (assuming that the underlying variable itself is continuous, which holds for intelligence).* An obvious implication is that the least intelligent individual in the series should obtain some definite score (other than zero), and the most intelligent individual in the series should obtain some score less than the maximum possible score. A good intelligence test—"good" in the sense of conforming to the notion of continuity of intelligence—should produce a series of scores with no zero and no perfect scores. A large proportion of zero scores, or of perfect scores, would serve to indicate that the test is unsatisfactory as a measure of intelligence at either one of the extremes. The same line of reasoning also applies to the subtests of a test.

*A distinction should be made between the scientific and practical aspects of the Army tests. A test which is not in accord with this principle may still be very useful as a practical instrument. As a scientific instrument, however, it requires congruency of this principle with obtained data. In this discussion, we are concerned with the Army tests as scientific instruments which measure intelligence.

TABLE I

PERCENTAGE OF ZERO SCORES ON SUBTESTS OF ARMY ALPHA AND ARMY BETA. COMPILED FROM DATA ON DISTRIBUTION OF SCORES FROM TABLES 436–39, PAGES 874–75, REFERENCE 3

| GROUP | PERCENTAGE OF ZERO SCORES ON SUBTESTS | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Test Alpha | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| White Draft (Group I) N = 33,100 | 5 | 2 | 10 | 25 | 20 | 12 | 15 | 8 |
| Negro Draft (Group IV) N = 6,560 | 20 | 10 | 33 | 55 | 40 | 35 | 50 | 30 |
| | Test Beta | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| White Draft (Group I) N = 7,500 | 7 | 8 | 11 | 12 | 15 | 3 | 18 | |
| Negro Draft (Group IV) N = 12,230 | 30 | 20 | 35 | 45 | 45 | 15 | 50 | |

With reference to the argument of the preceding paragraph, what is the situation insofar as the Army tests are concerned? Two things should be noticed in Table I: (1) the large proportion of zero scores for both groups; (2) the fact that the proportion of zero scores is much larger for the Negro group than for the white group. Point (1) indicates that the tests are not operative as measures of intellectual ability, at least in the lower ranges. Point (2) means that the Negro group, by virtue of factors possibly extrinsic to intelligence as measured by these tests, would be more adversely affected by the inclusion of zero scores than the white group. Furthermore, it should be realized that the various percentages refer to the Negro draft group as a whole. The percentage of zero scores for the Southern Negro draft group alone must have been in excess of 60 on some of the subtests.

With regard to the total Alpha score, there are similar discrepancies between Negro and white groups inso-



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far as the zero scores are concerned.† Seventeen percent of the Negro draft (Group IV), N = 6,327, attained zero scores (Table 254, p. 724).[3] Furthermore, there was much variation between states for this group. Thus, 34 percent of the Negro draft from Florida, N = 499, attained zero scores. On the other hand, the corresponding figure for New York was less than 2 percent, N = 197 (Table 254, p. 724).[3] The data for the white draft are not broken down in a manner to give estimates comparable to those of the Negro draft. There are indications, however, that the percentage of total zero scores for the white draft (Group I) was in the neighborhood of 2 percent (Pt. III, Chaps. 3, 4).[3]‡ This situation could have been predicted, since the percentage of the Negro draft getting zero scores exceeded the corresponding figures for the white draft on every subtest. Without going into the details, similar intergroup comparisons can probably be made with the results on the Beta test.

The practical conclusion of this discussion is that the Army test results should no longer be used in attempts to compare the intellectual status of the Negro with that of the white. Furthermore, the evidence based on these data, as typically presented in textbooks, should be properly revised so as not to give an incorrect impression of the validity of the primary data. These suggestions should not be interpreted as a denial of the value of these tests. In a history of scientific psychology, these tests, combined with the scientific and popular discussions engendered by them, and the stimulus they provided to the mental-test movement, will probably retain a significant position. The excesses that were associated with the interpretations of the test results probably derive from the peculiar postwar climate into which the tests were projected, rather than from their intrinsic merits or defects. It may be cogently argued, especially by those interested in the sociology of knowledge, that it was the presence of defects in the Army data themselves that paved the way for subsequent misinterpretations. The discussion of this matter really belongs elsewhere. Suffice it to add that the volume of the *Memoirs of the National Academy of Science* offers no decisive evidence as to the causes of subsequent misinterpretations.

† For this part of the discussion a zero score will refer to a score in the range 0–4, a range which, practically speaking, is equivalent to zero when the error of measurement is kept in mind. The data pertaining to total scores are grouped in intervals, the smallest of which is the 0–4 interval.

‡ The discrepancy in the proportion of zero scores may account for some facts implicit in the Army data which have not been elucidated to date. With a mental age of less than ten years as a criterion of feeblemindedness (in that period a widely used criterion was a twelve-year mental age), 77.7 percent of the Negro draft from South Carolina (N = 1642) should have been classified as feebleminded (Table 247, p. 721).[3] Parenthetically, the interval of 9–14 on the alpha test was assigned a letter rating of *D* minus, and the mental age equivalent of this interval and letter rating was 9.4 years or less. The corresponding figure for the white draft (N = 581) from the same state is about 8 percent (Table 205, p. 690).[3] This difference may have a sufficient explanation in its association with a like difference in the proportion of zero scores. Furthermore, the absurdly high figure of 77.7 percent in itself would be interpreted by pyschologists today, and probably thirty years ago as well, as meaning that the Army tests were defective as measures of intelligence.

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## MORE ABOUT STATISTICS

I have just read with great interest Professor McConnell's article "ESP—Fact or Fancy" (August 1949). In the first main section of this article he describes three sets of trials with the standard Rhine deck. The descriptions of these three experiments close with the following statements:

"The probability of such a score by chance alone is less than $10^{-20}$."

"There is no need to apply statistics to such a score to recognize its extra-chance character."

"The probability that this might occur by chance is about 0.000,000,000,064."

Absolutely independently of whether the experiments in question are or are not significant, I would wish to urge most warmly that these statements are irrelevant and misleading.

The mere fact that an event which has occurred has a very small a priori probability does not at all justify one in concluding that something other than chance has operated. Has Professor McConnell, by any chance (negligibly small, of course), read the article "Probability, Rarity, Interest, and Surprise" in the December 1948 issue of THE SCIENTIFIC MONTHLY?

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